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A SIMULATION MODEL
OF ATTACK HELICOPTER VULNERABILITY
TO HOSTILE ARTILLERY FIRE

THESIS

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PREFACE

This research was performed to provide some quantitative estimates of the Army's attack helicopter vulnerability to a hostile artillery threat. To the extent specified by the stated assumptions and constraints, the answers to this vulnerability issue are available from the simulation model described in this thesis.

Thanks are due to Major Ed Duff of the Fighter Division, Air Force Studies and Analyses, for his continuing interest in this thesis and for his many useful suggestions which properly defined the scope of this research. Major Dick Kulp was extremely helpful in all matters pertaining to probability theory, and the difficulties encountered in writing this model's target location error algorithm were resolved by him. Captain Jerry Sullivan was instrumental in gathering the much needed feedback from the Army pilots at Ft. Hood, Texas.

A very special thanks goes to my wife, Sandy, for her encouragement throughout the life of this project.

Emil H. Koenig, III

(This thesis typed by Sharon A. Gabriel)

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ABSTRACT

This thesis presents a methodology which simulates the activity, near the FEBA, of the Army's attack helicopter and the activity of hostile artillery in two formats : uniformly distributed area fire and precision fire against a point target as directed by a forward observer. A stochastic computer simulation was developed that varies the modeled activities from one replication to another. Current concepts of attack helicopter employment in the anti-armor role are used. Concepts of intervisibility, detectability, target location error, C-cubed time delay, and artillery round-to-round dispersion are also incorporated in the model. The model was experimented upon, using a hypothetical artillery weapon system, and the vulnerability predictions of the model are displayed and analyzed.

A SIMULATION MODEL
OF ATTACK HELICOPTER VULNERABILITY
TO HOSTILE ARTILLERY FIRE

I. INTRODUCTION

This thesis is a modeling effort to predict the vulnerability of the Army's attack helicopter (AH) to hostile artillery fire while the helicopter is being operated near the Forward Edge of the Battle Area (FEBA) in its armor defeating role. The research reported here involves the development of a computer simulation model that calculates, within appropriate assumptions and constraints, the AH probability of kill (P_k) in this particular battlefield environment.

To simulate the armor defeating role, the AH movement on the battlefield is structured to conform to the Army's current concept of employment for this weapon system. The effect of battlefield threat systems other than hostile artillery, whether acting independently or cumulatively, is not simulated. Additionally, "near the FEBA" is taken to mean a discrete portion of the land mass within which artillery is the only simulated threat to AH survival, and outside of which no threat to the AH exists. The hostile artillery fire is laid down in two formats: (i) a uniform area fire simulating the enemy's preparation of an area of intended conquest, and (ii) precise indirect fire simulating

observer-directed action against an AH point target of high interest.

The predicted vulnerability during these specified battlefield conditions is a primary accomplishment of this work. The sensitivity of this vulnerability to changes in several of the main variables of interest is also of importance because of the amount of uncertainty present in estimating parameter values.

The Problem Statement

The problem is that very little quantitative information exists which predicts AH vulnerability to hostile artillery fire while the helicopter is being operated near the FEBA.

The shallow extent to which this topic has been previously studied was verified by a rather thorough literature search of documents held by both the Defense Documentation Center and the Defense Logistics Studies Information Exchange. The vulnerability mentioned in this problem statement is defined to mean the probability that the AH, during any single exposure event in the target area, will experience an aircraft kill from any or all of the effects of the nearby detonation of high explosive, contact detonating artillery warheads. As used in this thesis, an aircraft kill is either attrition of the helicopter or a forced landing within 30 minutes.

Thesis Arrangement

Because some classified data were used in this study, a thesis format was necessary which would allow for the widest dissemination of the methodology and, yet, safeguard the sensitive information. As a result, this thesis is written in two documents, the bulk of which is this main report that includes, by way of example, the effects of a hypothetical artillery system. When specific enemy threat data versus the AH were considered, the results are discussed in the classified Appendix B to this main report. When it becomes necessary to acknowledge classified documents in this main report, the reference will be by title only.

Goals

Several goals were set at the outset of this work in order to properly measure the degree to which the thesis' overall objective was being met, that objective being to develop a method to answer "how vulnerable is the AH to hostile artillery fire?". These goals were:

1. Construct a computer model to simulate the artillery fire versus AH environment.
2. Test that this model behaves properly by applying both internal verification and external validation.
3. Perform sensitivity analysis upon the main parameters of interest.
4. Draw general conclusions about the AH vulnerability to the artillery threat based upon the model's output.

Importance of This Study

There are several reasons why this problem is being studied in addition to the purely academic goal of gaining a better understanding of what computer simulation is all about. Foremost, this is a topic of current Air Force interest. The Fighter Division, Directorate of Studies and Analyses, Headquarters Air Force, suggested this topic as a candidate for a thesis study and this office has actively supported the research. Secondly, by constructing a computer model and then documenting the thought processes used in the model's development, one should obtain a better understanding of the real world physical processes whereby artillery is indeed a threat of some concern to the AH force. Finally, by experimenting with the model over some reasonable ranges of the interesting parameters, an understanding may be gained as to how sensitive helicopter vulnerability, as predicted by this model, is to changes in friendly tactics and enemy capabilities.

Model Application

If this simulation model succeeds in addressing the relevant issues and interactions among battlefield resources, it may find broad use in developing input vulnerability data to tactical simulation models of far larger scope. One example of a larger scope model is the USAF TAC WARRIOR model. It is also clear that there is yet much to be accomplished in studying this relatively

small facet of the overall Close Air Support issue. Hopefully, this thesis can act as the basis model for any future sophistication that may be desired.

Thesis Overview

Chapter II, Background, puts this thesis in proper perspective by reviewing previous studies which have addressed this problem. Included in this chapter is a description of the various weapon systems that were modeled in this simulation. Chapter III, The Methodology, explains what real world events were made a part of the model and the manner in which these events were allowed to interact. Also in Chapter III is the discussion of how the model was validated. Chapter IV, The Simulation Model, contains the details of the computer model including a description of the model's logic and mechanics. Chapter V, Sample Results, demonstrates the model's capability by showing the output produced from the consideration of a hypothetical artillery weapon. Finally, Chapter VI, Summary, Conclusions, and Recommendations, provides a recap of the main points, draws conclusions based upon the model's performance, and illuminates those shortcomings in the present effort which, if corrected, should produce a better product.

II. BACKGROUND

This chapter is intended to provide the reader with a better perspective of the scope of this problem. It does this by describing some important points made by previous studies of this topic and related issues. Following this are some observations which have been made about the AH's vulnerability to artillery fire. Finally, the primary weapon systems which are modeled in this computer simulation are described in sufficient detail to acquaint the reader with their capabilities and concepts of employment.

Previous Studies

Many models have been constructed which attempted to quantify the events which happen in a land battle and the subsequent effects of those events upon the forces in the field. A large share of this effort are the models that attempt to simulate the exchange of all types of fires between opposing forces and to specify the result of such fire on the disposition, strength and combat capability, and the viable options which remain for the engaged forces. One subset of these models includes fairly detailed studies of the Army's AH as it is being used in the role for which it is now designed : anti-armor. It certainly appears that such in depth analysis is fully warranted because it has been noted by Taylor that "the U. S. Army has to hold the Fulda Gap with fewer than fifty Huey Cobra armed

helicopters, against thousands of Warsaw Pact tanks...." (Ref. 1:29).

STATE II is a computer simulation which models the armor versus anti-armor battle at the company level (Ref. 2). It was used as the starting point for this thesis because it addressed a firepower issue and it structured the real world problem into a computer program that was highly event oriented. Although helicopters were not specifically mentioned as being players in this STATE II model, the AH concept and its inherent anti-armor capability could be adapted to this simulation.

Another report presented the results of an Army field experiment in which the primary purpose was to investigate "scout helicopter effectiveness in one of a variety of missions on the mid-intensity battlefield" (Ref. 3:1-1-1). An interesting observation made in this report was that, if the helicopter exposed itself during an unmask maneuver* for a period of 37 seconds, this "represented" a 0.15 probability that a ground delivered projectile would impact near the scout vehicle. This probability relationship was not substantiated with an explanation of the type of projectile (although direct-fire tank weapon could be inferred) or of how this relationship was derived.

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* The unmask maneuver is a flight maneuver whereby the helicopter leaves its hidden position behind cover or concealment in a pop-up to an altitude sufficient to provide line of sight to the target of interest. The remask is the reciprocal maneuver.

An older study that described an artillery assessment model which was a tool used in a war game called SYNTAC considered artillery fire against helicopters, but only against a fixed percentage of the helicopter force that would be in the artillery's target area. The difficulty with this approach is that this fixed percentage was the approximation of the numbers of helicopters that would be considered parked or on ground alert (Ref. 4:13). By design, this simulation model would not address the issue of artillery against a moving AH. It appears that this study assumed that the artillery is no threat at all to a helicopter in motion.

There have also been several recent classified Army studies which examined in great detail the artillery threat to the AH. These models differ from the model developed in this thesis in the level of detail of the environment which is incorporated into the simulation. For instance, one particular Army model requires that the user input a detailed description of the terrain over which the AH will fly, thus the results of such a model are applicable only to that particular geographic region. This thesis, by assuming average terrain features, presents a model that is more universally applicable. Also, this same Army model inputs specific point and area targets for the artillery fire missions to engage. These inputs were made as a result of close scrutiny of the terrain map by artillery officers. By contrast, this thesis simulates area wide coverage of

the artillery fire and, in addition, simulates the forward observer (FO) who attempts to direct fire specifically against the AH when detection occurs.

The Army is generally concerned about the AH vulnerability to artillery fire. As was discovered through dialogue with personnel at Ft. Hood, Texas, the artillery threat is viable enough to have influenced the planned disposition of the AH forces in the target area (Ref. 5). This concern is taken into account by the present tactics of AH employment. More simply stated is the fact that "quite obviously the helicopter has to vacate the artillery barrage areas, as will all other thin-skinned vehicles" (Ref. 6:57).

The AH-1Q/S

This Army attack helicopter is being produced in two versions, models Q and S, both of which are derivatives of the original Army Huey Cobra AH-1G. The main difference between these newer versions and the basic aircraft is that the newer versions have been equipped to employ the TOW (Tube-launched, Optically-tracked, Wire-guided) anti-tank missiles. This potent addition to the Army's anti-armor arsenal is generally referred to as the Cobra/TOW.

This AH is a single engine aircraft driving a two bladed rotor. It is operated by a crew of two whose stations are arranged in tandem. The gunner occupies the forward station, the pilot occupies the rearward station. This

weapon system is reported to have a maximum level speed of 123 knots with missile launchers on board and a maximum range of 507 km (Ref. 7:274-275).

The primary armament carried by the AH-1Q/S is the TOW missile. This missile carries a high explosive shaped charge warhead which was specifically designed to penetrate armor. The gunner provides guidance commands to the weapon from the time of launch until target impact occurs by keeping the target image centered in his gyro-stabilized gun sight. These guidance signals are passed to the missile through two wires which are unreeled during the missile's entire fly out. One AH-1Q/S can carry up to eight missiles at once. The maximum range attributed to this TOW missile system is 3750 meters (Ref. 8).

The role of the AH in modern battle, as stated in Field Manual 17-50, is to "destroy sufficient numbers of the enemy to convince him to break off his attack, to give up a defensive area, or to move away from an area vital to friendly forces" (Ref. 9:4-1). The method of destruction is, of course, the employment of the TOW missiles. However, the AH does not intend to accomplish this mission by acting alone. His partners on the battlefield are the Aeroscout helicopter and the friendly ground forces, both of which find tanks and other armored vehicles and provide this information to the AH. The Aeroscout helicopter is a more capable teammate for the AH than surface forces because the helicopter's high degree of mobility insures more frequent

contact with targets of the opposing side. In addition, the Aeroscout assumes the responsibility of providing local protection to the AH while he's engaging the targets.

A sequence of events that the AH could be expected to perform as he works with the Aeroscout on a combat mission might be:

Move to holding area

Coordinate with Aeroscout

Move to battle position and receive target hand off

Partially unmask

Acquire target

Unmask as required to fire

Engage - Remask - Move to alternate firing positions or return to holding area (Ref. 9:43)

A holding area is a site that the AH occupies, usually only for brief periods, while the Aeroscout is busy coordinating other AH movements into attack positions.

Threat Artillery

As is well known, the purpose of employing artillery is primarily to reinforce the offensive striking power of an aggressor. This is typically characterized in Soviet doctrine by the employment of massive fires, if the artillery resources are available (Ref. 10:2-13). The big bore weapons usually remain under the division or regiment operational control, but are supportive of the fire and maneuver plans of subordinate units as necessary.

As an example of this Combined Arms Armies concept of warfare, it is quite possible that a motorized rifle or tank battalion will receive the support of six large artillery pieces during an offensive operation (Ref. 10:2-19).

Two common artillery threat systems are the 122 mm Towed Howitzer (D-30) and the 152 mm Towed Gun-Howitzer (D-20). The 122 mm weapon is reported to have a maximum range of 15,300 meters and a rate of fire of seven to eight rounds per minute. The 152 mm weapon is credited with a 17,000 meter range and four rounds per minute rate of fire (Ref. 11:2-19). The probability of kill data for these two threat systems against the basic model AH-1G and the result of the simulation process while incorporating these specific weapon characteristics are contained in the classified Appendix B.

Forward Observer

The forward observer (FO), as simulated in this model, is a combatant who is equipped with an armored vehicle which permits the FO to remain near the other combat vehicles at the FEBA. His primary function is to see as much of the battlefield situation as is possible and to report sightings of targets of interest such as the Army's AH. The goal of this FO is to detect the presence of an AH anytime that intervisibility (an unobstructed line of sight) exists between his position and the AH's position, to measure as accurately as is practicable the location of

the AH, and to radio this target sighting to an artillery unit so that a concentrated artillery fire mission may be brought to bear upon that sighting. Specific Soviet FO capability and equipment is not included in this model. Instead, variables of interest which impact upon the FO's performance are programmed within a wide range of values to permit parametric study.

III. THE METHODOLOGY

Simulation Requirements

There are only a few basic requirements that the simulation model must perform in order that it become representative of the real world environment. The most important requirement is the proper synthesizing of the AH's movement on the battlefield. The desired movement algorithm must be one that is conceptually correct for the environment being modeled. For this thesis, the AH was allowed enough freedom of play to insure adequate randomness from one replication to the next; yet, this randomness was sufficiently bounded so that the overall pattern of movement is representative of the Army's current employment doctrine.

Another important modeling requirement is that the artillery be required to fall in the same area in which the AH is operating. Randomness is incorporated into this function both in the uniform area fire and in the precision fire against a point target.

The last major requirement is that simulated time within the model must be permitted to remain "frozen" while the effects of a critical event, such as an artillery impact near the AH location, is properly assessed.

Scenario

The portion of the battlefield in which the AH is most susceptible to attrition by artillery fire is that area which is likely to have the most artillery activity. A prime candidate for such activity is the area adjacent to the FEBA and this is what has been selected for use in this model.

Conceptually, this model begins monitoring the AH movement at some arbitrary position along its flight path from a holding area to the first battle position. This can be visualized as the AH movement forward to confront the threat, probably as a result of a target assignment by an Aeroscout helicopter. This type of AH employment is appropriate for an overall battle situation which is probably somewhat stable; i.e., there has been no dramatic toppling of the balance of forces and the FEBA is still fairly well defined.

Also in this model's scenario is the enemy's artillery fire missions. One mission is that of a preparation of the land mass by area fire (sometimes called barrage fire). This is simulated in the model by uniformly distributed impacts. The other type of fire mission is that which has been directed by a forward observer (FO) to be placed upon the observed location of an AH. This algorithm employs the applicable considerations of line of sight (intervisibility), detectability, target location errors,

C^3 delays, and weapon inaccuracies. The fact that such artillery support is readily available is consistent with the idea that a relatively stable situation is being modeled as opposed to such fast moving battlefield operations as exploitation.

SIMSCRIPT II.5

The SIMSCRIPT II.5 computer language was selected as the language of this computer model for several reasons. The main reason is that SIMSCRIPT II.5 is appropriately structured to handle time dependent routines or events. The language's built-in timing routine greatly simplified the scheduling of the many events which the model is performing. Another useful feature of this language is that an interface is provided which allows for linking a FORTRAN subroutine, as necessary, to the main simulation program. This particular ability was required to enable the execution of the plotting package which produced many of the figures contained in this thesis.

Because of software incompatibility, the AFIT implementation of the SIMSCRIPT II.5 language did not allow for the user of the model to be interactive with this program at an on-line terminal. This mild limitation presented no difficulty in the development of this thesis; however, interactive capability may be worthwhile in future attempts to update or change this model.

Goals Accomplished

The first goal of this thesis was accomplished by the construction of the computer model described in this paper. This was done by building into this model the known characteristics of the weapon systems, a typical scenario, and an established employment doctrine.

The second goal was the testing of the behavior of the model. This was conducted in two ways. The internal verification was done to insure that the functions within the model were operating as planned. This proper behavior was confirmed by the examination of numerous plots of the model's data output. These plots were executed on AFIT's CDC 3292 Incremental Plotter device. An example of the type of graphics which were produced by the plotting package is contained in Figure 1.

This is a typical ground track portrayal of the AH movement which begins at A, proceeds to firing positions close to the "front" of the operating area, then exits at B on the return leg to re-arm and/or re-fuel. The plotting routine which accomplished this is called SUBROUTINE SCRIBE and its FORTRAN code listing is included in Appendix A along with the SIMSCRIPT II.5 code for this computer model.

The external validation of the model was done by preparing a series of representative graphics, similar to Figure 1, which were then sent to Army personnel for informal

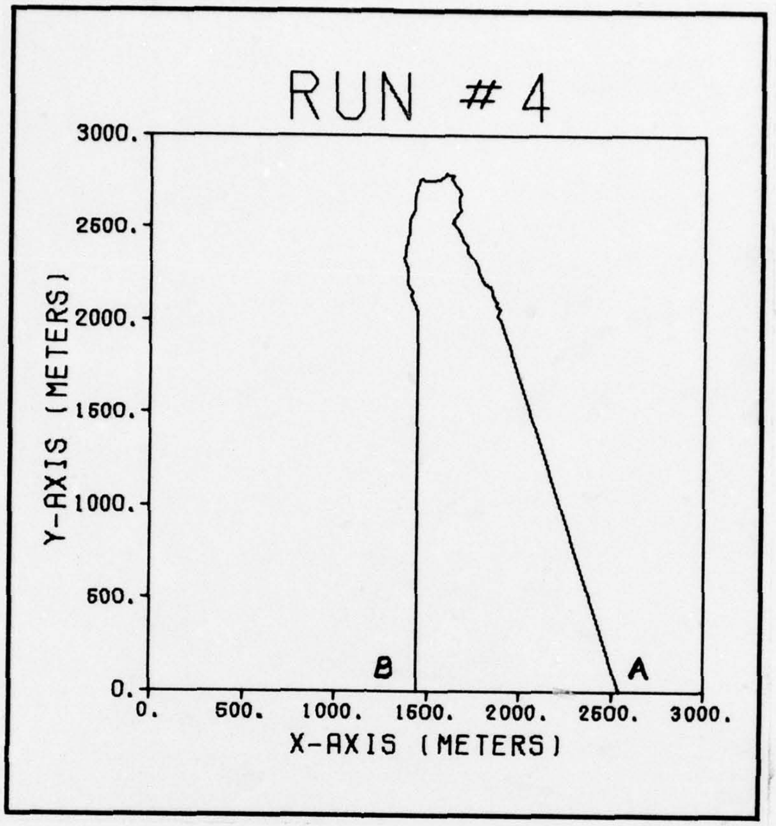


Figure 1. Sample Graphics

critique. The personnel who participated in this feedback of information were highly qualified Cobra/TOW aviators, usually with Vietnam combat experience, assigned to the 6th Air Cavalry Combat Brigade at Ft. Hood, Texas. An interesting example of the kinds of information that were provided by the Army included a strong recommendation that the AH holding area not be included within the initial target area boundaries of 3000 meters by 3000 meters. This holding area was originally built into the model to conform to Army guidance in Field Manual 17-50 which envisioned the holding area as being a location near enough to the FEBA

to allow for the AH's fast response to any target assignment. However, as pointed out by the Cobra/TOW pilots at Ft. Hood, this holding area would be selected based upon the reality of the situation and this includes avoidance of the enemy's artillery fires, if possible. As a result, the holding area concept was taken out of the model.

The model was also validated to a certain degree by the adaptation of two algorithms that were obtained from outside sources. One algorithm was the line of sight model which was written by David C. Hardison, currently an Under Secretary of the Army, and included in a paper presented to the Terrain Modeling Working Group at a Colorado Springs meeting in August 1977. It has been used in the joint Air Force/Army project called the NATO Fire Support Requirements Study.

The other algorithm is the detection subroutine of the Night Combat Model developed by the Army's Night Vision Laboratory. This program has been used as the acquisition probability subroutine for the Army Materiel Systems Analysis Activity model called War Game and the Battalion Level Differential Model. The Army's Concepts and Analysis Agency is also using this algorithm in the Carmonette Model. Both routines are fully explained in Chapter IV.

The third goal, which was the sensitivity analysis upon the main parameters of interest, was performed by making many single-factor experiments of the model. The

impact upon the P_k of varying the values of the main parameters are shown in graphical form in Chapter V for the hypothetical artillery system and in Appendix B for the Soviet 122 mm and 152 mm Howitzers.

The final goal was to make general conclusions about AH vulnerability to the artillery threat. These conclusions were made based upon the P_k output from this computer model. The conclusions are a part of Chapters V and VI.

Primary Variables of Interest

The user of this model is required to select the values of many different variables; thus, any particular run or series of runs will be expressly tailored to the user's needs. Each variable value, of course, can become the basis for as much in depth testing of the model's results as is desired. Through discussion with personnel at the Fighter Division, Directorate of Studies and Analyses, Headquarters Air Force, it was decided that four of the variables in this model would be examined in some detail.

One variable is the amount of time that the AH remains in its initial battle position prior to commencing the first TOW engagement. This was built into the model to simulate the time required for final strike coordination between the AH and the Aeroscout. In this model, that amount of time is represented by the input variable CALL.TO.FIRE. This loiter time is not applied to any subsequent reattacks that the AH may accomplish during any replication. This

simulates that additional targets are seen by the AH during its initial TOW engagement and that the Aeroscout is not needed to generate these subsequent targets. This CALL.TO.FIRE variable was allowed to take on values between 0 seconds and 180 seconds. It should be noted that a fixed time delay is incorporated at each attacking position, whether it's the initial battle position or a reattacking position. This time constant is 35 seconds, which is the written guidance to the AH crew, and it represents the upper bound of time which should be spent in the TOW firing operation (Ref. 9:4-9).

Another variable is the intensity of the artillery's area fire. Since the area fire continues without slack or interruption during the AH's entire stay in the target area, the intensity is dependent only upon the rate of fire. Control of this intensity parameter is achieved by simply changing the value of T1 which is the time interval, in seconds, between successive artillery round impacts. This T1 parameter was allowed to have values between 2 seconds and 20 seconds.

The target location error was another variable of interest. This parameter is the radius, in meters, of a circle drawn about the AH's exact position. Inside of this circle, all points are equally likely to be selected as the FO's determination of where the AH truly lies. Labeled TLE, this target location error takes on values between 10 meters and 100 meters.

The last variable of interest in this thesis is the time which elapses between the instant that the FO detects the presence of the AH target and the instant that the first round of the precision fire hits the target area. The concept of this time delay embodies such mission related activities as : the FO must translate this target detection into an appropriate set of map coordinates, the request for the fire mission must be radioed to the supporting artillery unit, the artillery unit must convert the target coordinates to the appropriate tube alignment parameters, and the first round must experience the appropriate time of flight. It was desired that this timing delay variable would primarily represent the C^3 delay aspect of the above chain of activities; thus, it is named C3.DELAY and it ranged in value between 0.5 minutes and 3 minutes.

Replication Planning Factors

To compile the object deck on AFIT's CDC 6600 system takes, on the average, 19 seconds of Central Processing (CP) time and requires 71000 octal words of Central Memory. Trial runs have shown that the execution phase of the model generally consumes 14.4 seconds of CP time per 100 replications. One replication is one entry and exit of the AH for the Area of Operations, including all AH movement in between, all artillery activity, and any damage assessment calculations which may be necessary.

It was desired that the overall P_k calculation be within ± 0.03 of the true, but unknown, P_k. Also, a 90% level of confidence was desired for the range selected. As shown in Shannon (Ref. 12:192), the number of required replications (n) to achieve the 0.03 upper and lower P_k bound (d) is related to the two-tailed standardized normal statistic (Z) by

$$n = \frac{\left(Z_{\alpha/2}\right)^2}{4d^2} \tag{1}$$

where $Z_{\alpha/2} = 1.645$ for the 90% confidence level.

This yields 752 required replications, which equates to approximately 108 seconds of CP execution time for each P_k data point desired. Based upon this analysis, the model was replicated 752 times for each changing level of a main parameter. This plan was followed for all of the computed data points which are plotted in Chapter V and in Appendix B.

IV. THE SIMULATION MODEL

This chapter explains the development of the individual routines of the simulation model. The routines of the SIMSCRIPT II.5 language are labeled as events and these events are scheduled for execution by the built-in timing routine. The complete code listing for this model is contained in Appendix A.

The AH is always constrained to remain within the Area of Operations (AO) boundary, whose size is determined by the user. These dimensions, labeled X.MAX and Y.MAX, were set at values of 3000 meters each for all of the sample replications in this research. The AO is depicted in Figure 2.

The x-axis of this coordinate system is the line farthest away from the armor threat, and the y = 3000 meters line is the closest. Conceptually, the enemy's first line of armored vehicles is simulated to be on a line at y = 5500 meters. Thus, it is assumed that the AH does not proceed any closer than 2500 meters to the armored threat which the AH is designed to defeat.

Event NOE

Event NOE, when scheduled, generates a randomly oriented flight path between the AH's currently occupied position and the ultimate destination. This is accomplished

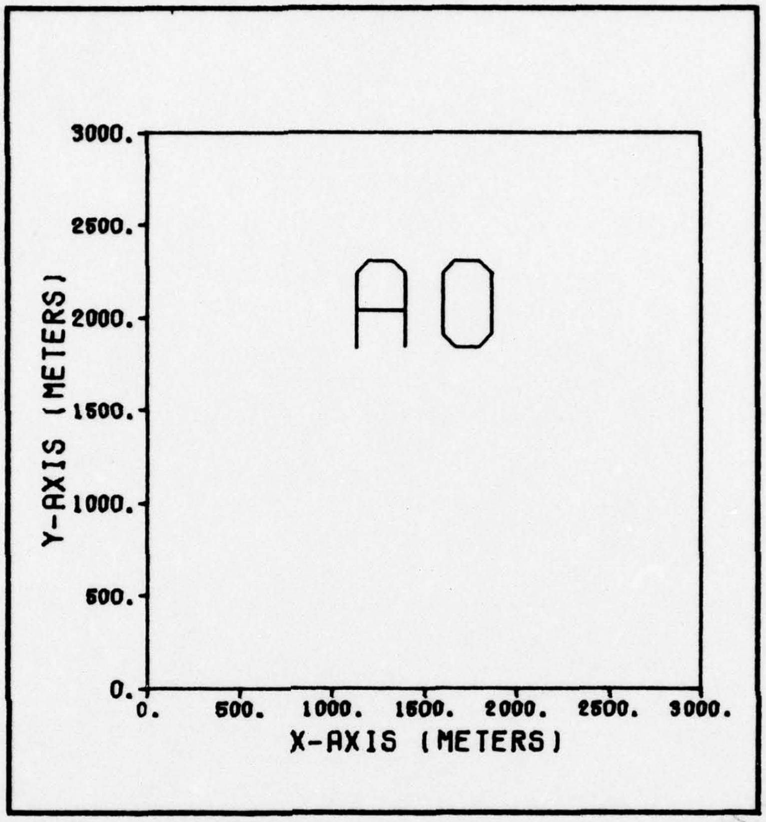


Figure 2. Area of Operations

by generating, at fixed time intervals, individual velocity vectors for the AH to maintain. These small velocity vectors randomly vary from one to another in magnitude and direction. This was done to simulate nap-of-the-earth flight which Field Manual 17-50 defines as flying a "weaving slalom-like route within the planned corridor while remaining oriented along the general axis of movement" (Ref. 9:4-8). These velocity vectors were used to specify the series of discrete points that the AH is to occupy on its travels in this particular mode of flight. The flight

path maintained between each of these discrete points was assumed to be straight line and at constant velocity.

The magnitude of each velocity vector was a function of the fixed time interval (DEL.T) and a variable airspeed term. This variable airspeed was randomly drawn from a uniform distribution with an upper and lower bound of LOSPEED and (0.5)LOSPEED, respectively. The user inputs the DEL.T value in seconds and the LOSPEED value in knots. For this thesis, values of 6 seconds and 15 knots were used.

The direction of the vectors also varied from one to another. This part of the algorithm consisted of defining the straight line path between the AH's currently occupied position and the ultimate destination. An angular deviation from this path was randomly drawn from a uniform distribution between ± PHI.MAX. PHI.MAX is entered by the user in units of degrees, and 45 degrees was the value used in this research.

Since the AH's currently occupied position is always stored by the model and the magnitude and direction of the newly generated velocity vector has been specified, vector addition was used to provide the coordinates of the AH's next position. This iterative process was executed once each 6-second period until the AH finally arrived at its destination. An example of the nap-of-the-earth ground track generated by the Event NOE is shown in Figure 3.

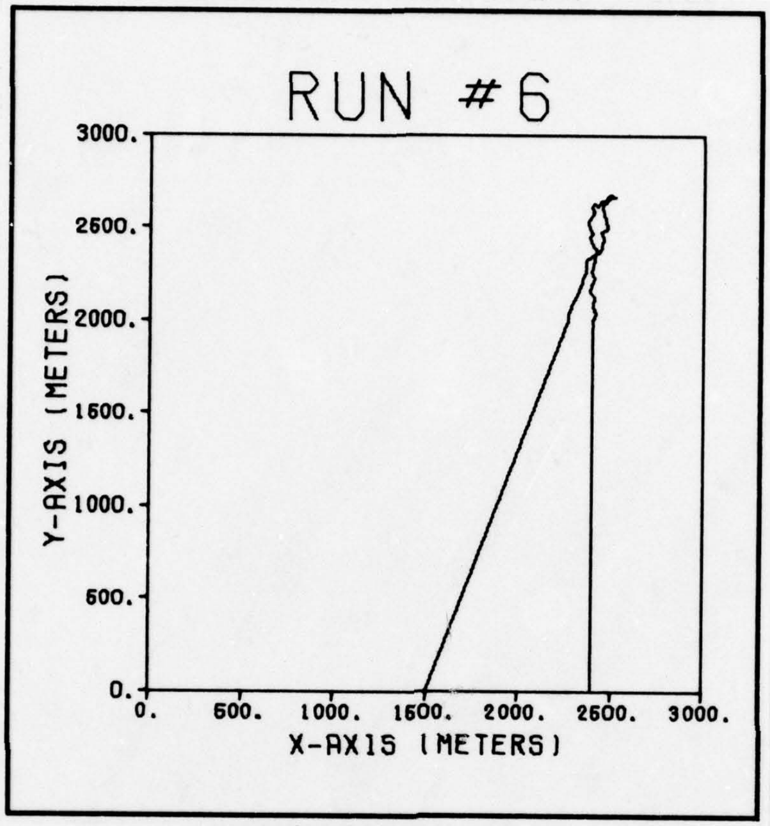


Figure 3. Nap-of-the-Earth Ground Track

All of the movement which is depicted above the y = 2000 meters line was generated by the Event NOE. The constraint that the AH must employ nap-of-the-earth flight whenever it is within 1000 meters of the front edge of the AO was formulated through discussion with the Ft. Hood aviators previously mentioned in this thesis.

Event LOS

Event LOS determines whether or not unobstructed line of sight (intervisibility) exists between the FO and

the AH. Event LOS is represented by the top step of the logic flow chart in Figure 4. An adaptation of the Hardison line of sight algorithm, first mentioned in Chapter III, is used. This event is executed once every 10 seconds of simulated time. The calculation of the probability that line of sight exists is a function of target-to-observer range (R), terrain type coefficient (K), and the observer's viewing height (H) above the terrain. These variables are related to the probability of line of sight by:

$$P_{LOS} = \left(\frac{2R}{\overline{R}} + 1 \right) \exp \left(\frac{-2R}{\overline{R}} \right) \qquad (2)$$

where $\overline{R}$ is $K \left[A_i + B_i \, (H/100)^{C_i} \right]$, R is expressed in kilometers, H is in meters, and A_i, B_i, C_i are modified target coefficients. For this thesis, values of $A_i = 1.56$, $B_i = 3.48$, $C_i = 1.173$, $K = 1.0$, and $H = 3$ meters were used. The A_i, B_i, and C_i coefficients were sample values suggested by the Fighter Division, Directorate of Studies and Analyses, Headquarters Air Force. The K term is based upon the type of terrain being simulated and it has these representative values:

smooth terrain	K = 1.9
rolling terrain	K = 1.0
rough terrain	K = 0.3 .

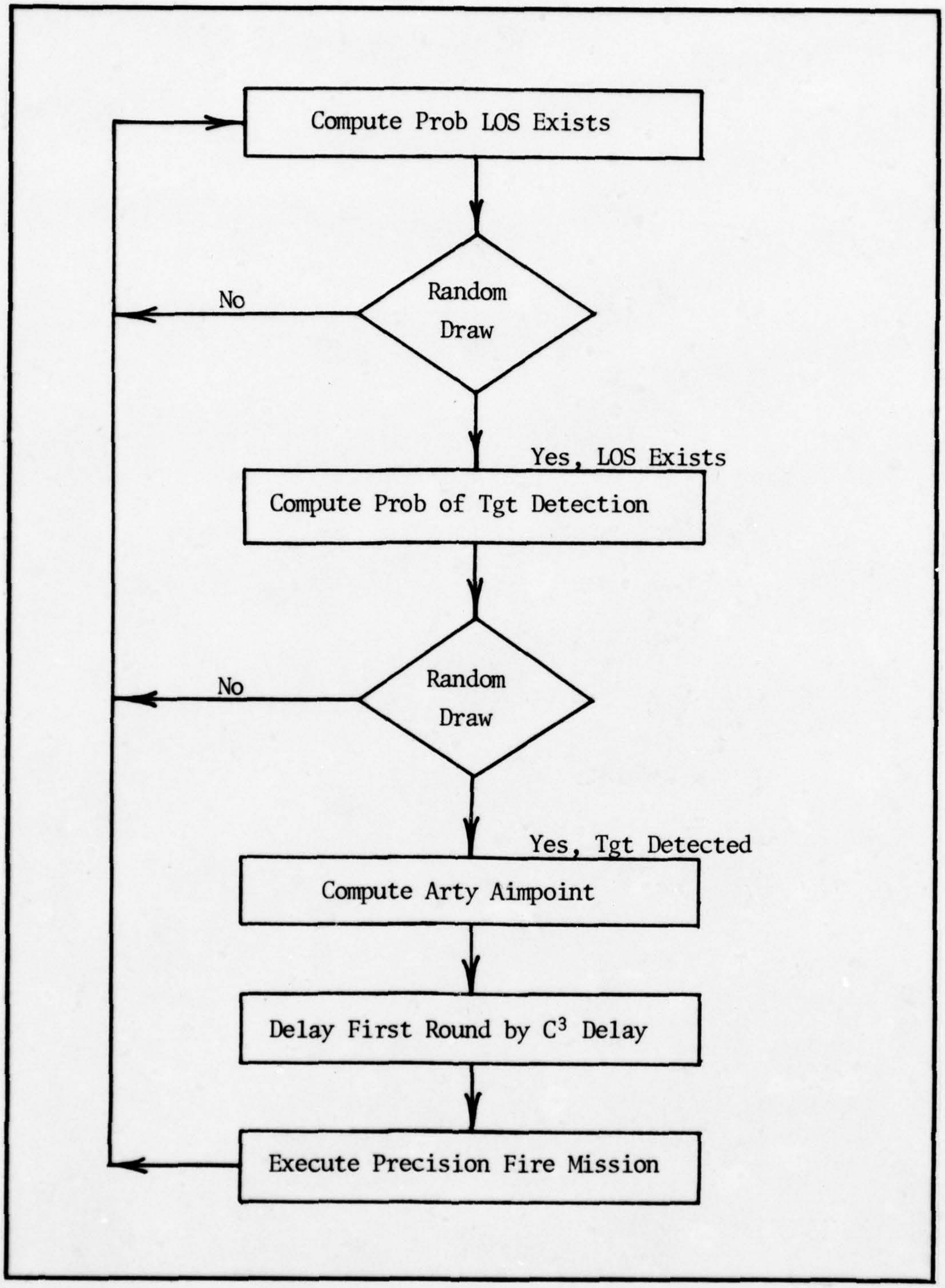


Figure 4. Logic Flow Chart

The user of the model must specify the values of K and H .

This Event LOS, after calculation of the P_{LOS} at each 10-second interval, draws a random deviate from a uniform (0,1) distribution and compares this deviate value with P_{LOS}. For those instances when the deviate value is less than or equal to P_{LOS}, line of sight is presumed to exist and the detection algorithm (Event DETECT) is then executed. Otherwise, another line of sight iteration is scheduled after the required 10-second delay.

Event DETECT

Event DETECT is essentially a language modified edition of the Army's Night Vision Laboratory-developed Detection Subroutine of the Night Combat Model. The original FORTRAN coding was rewritten in SIMSCRIPT II.5 language. This algorithm is executed for the target-to-observer range at the instant that line of sight exists in the model. The algorithm calculates the probability of target detection as a complex function of the viewing device's capability to respond to the target's presence and of the observer's capability to recognize this device response as a target signature. The routine calculates this detection probability by applying light levels and target/background contrasts to the number of resolvable line scan cycles required by the observer to make a target detection. A curve-fitting technique is then employed to fit empirical data to these specific encounter parameters to arrive at the appropriate

probability of detection.

The following assumptions were built into the Event DETECT. The FO must acquire and be able to classify a target image to a sufficient degree as to be able to distinguish between tracked versus wheeled vehicle. The meteorological conditions are seven kilometer visibility range and the atmospheric attenuation coefficient is 0.558 . The reflective contrast between AH and its background conditions is a fixed ratio of 0.3 . The sky brightness to ground brightness ratio is 3.0 . The FO is searching a 20° x 30° area and using 7-power binoculars. Thirty percent of the available light into the binoculars is lost due to optical attenuation. The only user input into this algorithm is the ambient light level (AL1), measured in foot-candles, at the target. This research used AL1 = 1000 foot-candles to simulate bright sunlight.

The end product of this algorithm is a computation of the probability that the FO will detect the target within a 10-second period after line of sight conditions occur. This value is called P10. A random deviate is then drawn from a uniform (0,1) distribution and this value is compared to P10 to make a decision as to whether or not detection has occurred. If detection occurred, a precision fire artillery mission is begun; otherwise, the line of sight event is re-scheduled.

Event PREC.FIRE

Event PREC.FIRE determines the magnitude of the precision fire activity. The user controls this process by specifying the maximum number of rounds that may be employed during any single precision fire mission. This parameter is called ROUNDS. Also, the user specifies the value of ROF, which is the rate of fire parameter. Values of ROUNDS = 40 and ROF = 8 rounds per minute were used in this research.

While a precision fire mission is being executed, the line of sight event in the model is discontinued. Event PREC.FIRE re-initiates the line of sight algorithm after the precision fire mission has been completed.

Event PREC.FIRE also incorporates the concept of a C^3 time delay between when the AH detection has occurred and when the first round of the volley impacts the target area. The user specifies this value of C3.DELAY in minutes and, for this thesis, a value of one minute was used for those replications which did not apply any sensitivity to this variable.

The algorithm which derived the weapon's aiming point coordinates is also contained in Event PREC.FIRE. At the instant of AH detection, the AH's position (X22,Y22) is passed to this event. It was desired that the forward observer (FO) specify an aiming point which would randomly lie within a circle of radius TLE, centered about (X22,Y22).

Also, this randomness concept was interpreted to mean that all points within the "TLE" circle could be selected by the FO as the ultimate aiming point with equal probability. To achieve this condition, a polar coordinate frame of reference was used with the origin at (X22,Y22) and the initial line positioned as would a positively oriented x-axis. The direction coordinate (BETA) was randomly drawn from a uniform distribution between 0 and 2 π radians. The length coordinate (RHO) is the product of the user's specified target location error (TLE) and the square root of a random deviate drawn from a uniform (0,1) distribution. This BETA and RHO deviation was then applied to the (X22,Y22) coordinate to specify the aiming coordinate (AIMX,AIMY). For those replications of the model which did not vary the target location error, a fixed value of TLE = 50 meters was used.

Event THREAT

Event THREAT serves many functions. If the model has scheduled this event in order to apply another artillery impact for the simulated area or barrage fire mission, the required impact coordinate is drawn from two different uniform distributions whose range of values are from 0.0 to X.MAX and from 0.0 to Y.MAX. This was done to make any point within the AO as equally likely to be selected as any other point. The user controls the intensity of this artillery activity by specifying the value of T1. This T1

variable is the time interval, in seconds, between successive artillery impacts. Figure 5 is the plotting of all area fire impacts that occurred during a single replication of the model in which the AH remained in the AO for 8.409 minutes. The frequency of artillery impacts was once every five seconds.

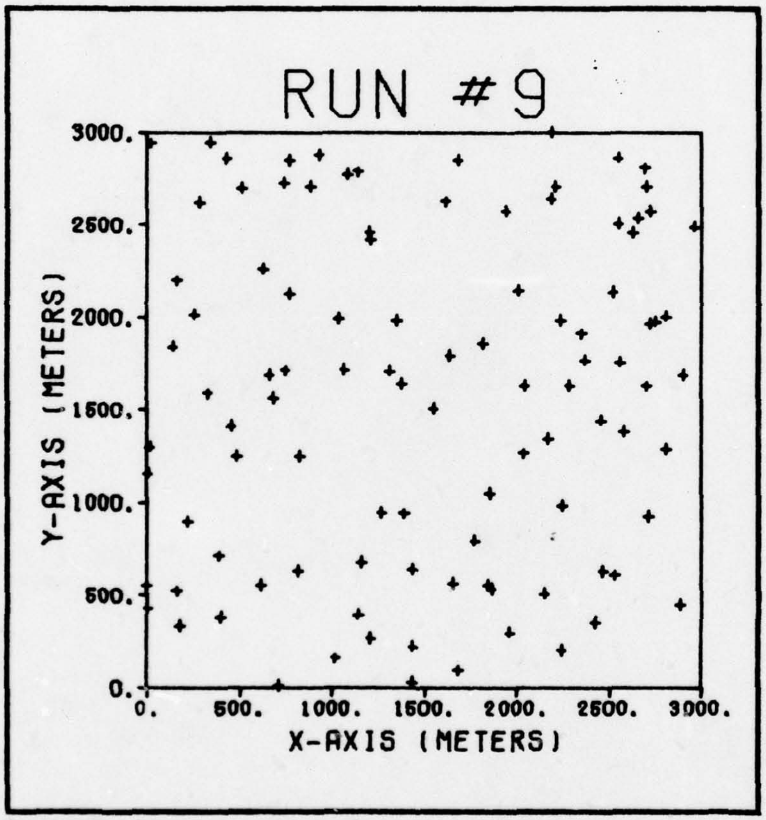


Figure 5. Area Fire

However, if the Event THREAT is scheduled because detection of the AH has initiated a precision fire artillery mission, this routine determines the impact point of the

round based upon the aiming coordinates (AIMX,AIMY) which were passed to it from the Event PREC.FIRE. The user has control of the footprint size of the precision fire mission by specifying values for PE.R and PE.D, in meters. These parameters are the probable error in range and probable error in deflection of the single gun being simulated. Since probable error is generally defined to mean 0.6745σ (σ = one standard deviation of the distribution of the fall of shot), the algorithm which specified the random deviate that represents the gun's dispersion drew from a normal probability distribution function of mean 0.0 and standard deviation PE/0.6745. The deflection deviate was added to the x-coordinate of the aiming point and the range deviate was added to the y-coordinate. An example of an application of 40 rounds of precision fire against an aiming point is depicted in Figure 6.

As is shown in Figure 6, the uniformly laid area fire continues to be applied, unaffected by the generation of the precision fire mission. In Figure 6, a rectangle was drawn which was centered about the gun's aiming coordinates. Based upon the definition that PE = 0.6745σ, on the average such a rectangle should contain 50% of the impacts of this precision fire algorithm.

The final function of Event THREAT is to compute the P_k of each artillery impact against the AH and store this value for future computation. This operation is accomplished

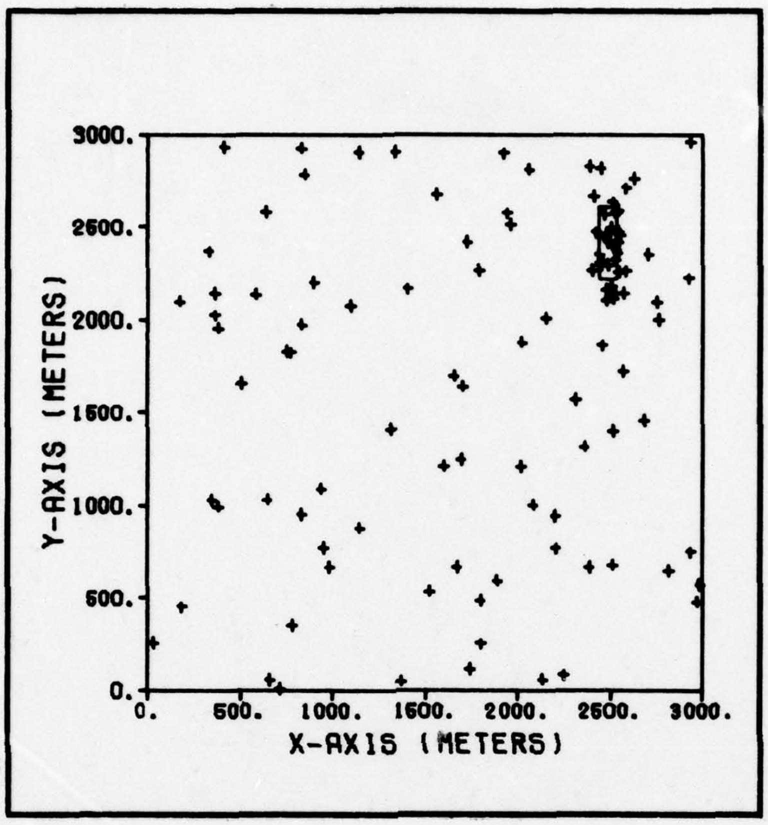


Figure 6. Precision Fire with Area Fire

by first checking the range between AH position and artillery impact at the instant of simulated detonation. For those rounds which land outside of the maximum range at which any hazard to the AH is expected, the P_k computation is disregarded and the Event THREAT is terminated. For those rounds which land inside of this maximum range, a search is made through the threat P_k data array and the two P_k data entries which are nearest to the range in question are found. A linear interpolation between these end values

of P_k is performed. The resultant P_k for this particular encounter is then stored in an array called PKS and the artillery's impact coordinates are stored in arrays called PK.X and PK.Y. Tests made upon this P_k algorithm have shown that this linear interpolation technique never exceeds a 10% error from the actual P_k value and it generally is within 3%.

The Scenario Events

There are several events in this model which are related to one another in the sense that these events control the details of the scenario which make any replication different from any other. Their event names are SCENARIO, INGRESS, ENTRY.LEG, 1.REATTACK, 2.REATTACK, 3.REATTACK, DROPBACK, and EGRESS.

SCENARIO acts as the traffic controller by scheduling other scenario related events, as appropriate. Events ENTRY.LEG and EGRESS control the two high speed profiles, which simulate low level flight, in which the AH is in a straight line flight path either into or out of the AO. The speed at which this maneuver is accomplished is controlled by the user when he specifies the value of the variable HISPEED, in knots. Once specified at the beginning of program execution , HISPEED remains constant. HISPEED = 50 knots was the value used in this research.

Event DROPBACK controls the transition between the nap-of-the-earth profiles, which are used by the AH near

the simulated TOW firing positions, and the high speed egress from the AO. As an additional function, Event ENTRY.LEG provides similar transition between the high speed ingress and subsequent nap-of-the-earth flight. The coordinates at which these transitions are made are labeled in the model as (XSLOWDOWN,YSLOWDOWN) and (XSPEEDUP,YSPEEDUP). Events 1.REATTACK, 2.REATTACK, and 3.REATTACK control the execution of the AH's movement to alternate firing positions, as dictated by Event INGRESS. It should be noted that the unmask and remask flight maneuvers, usually associated with TOW engagements at the firing positions, is not simulated in this model.

Event INGRESS is the workhorse of this entire package of events. The most important product of this event is the random determination of how many reattacks are to be made by the AH, if any at all. During any one replication, it was desired that four options be available to the AH corresponding to 0, 1, 2, or 3 reattacks, and that each option be equally likely to be selected. This was done by drawing a random integer (I2) from a uniform (0,3) distribution. If I2 was returned with a value other than zero, any subsequent reattacking locations were biased toward the center of the AO to prevent the AH from ever exceeding the lateral boundaries. Also, these reattacking locations were allowed to vary from the previously occupied firing position uniformly between ± 50 meters in the

y-coordinate and uniformly between 30 and 150 meters in the x-coordinate. Additionally, the Event INGRESS specifies, in a random manner, the entry and exit points, the initial battle position, the FO's position, and the SLOWDOWN and SPEEDUP coordinates.

Figure 7 is an example of what the AH's ground track, as generated by this model, might look like.

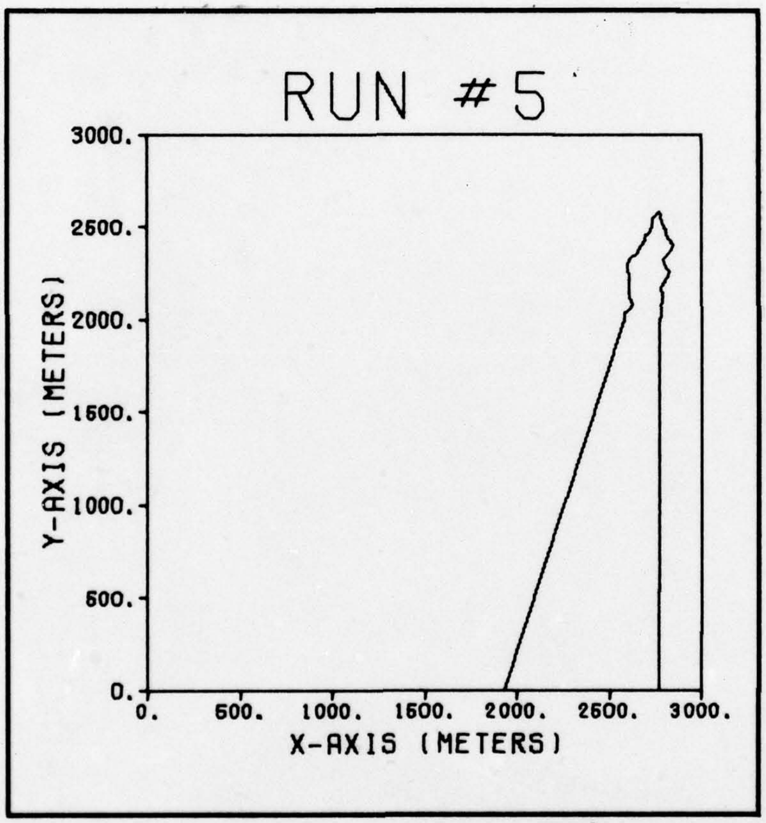


Figure 7. Sample Ground Track, No Reattacks

During this particular replication, the AH was not directed to perform any reattacks. Consequently, after the

allotted time was spent at the initial battle position, the AH employed nap-of-the-earth flight until a point was reached that was 1000 meters away from the forward edge of the AO. Then, low level flight at 50 knots was flown from that point along the shortest straight line segment to the rearward edge of the AO. The AH spent 7.675 minutes executing the ground track which is depicted in Figure 7. This may be compared with Figure 8, which shows a different replication of AH ground track activity.

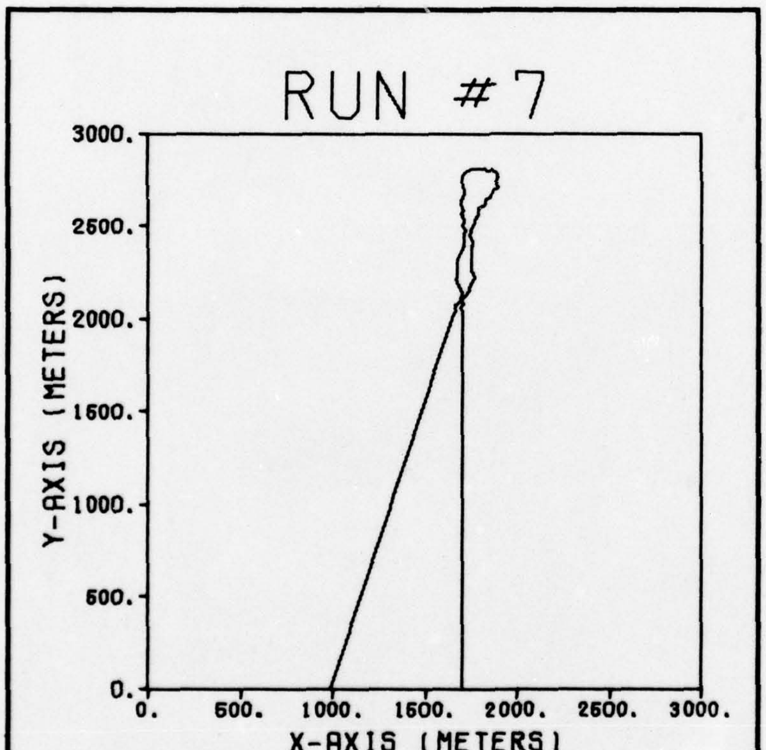


Figure 8. Sample Ground Track, 3 Reattacks

As can be seen, the randomly generated scenario within the model produces completely different ground tracks at each replication. For the run depicted in Figure 8, the AH made three reattacks. The initial battle position is the upper right hand point of the ground track. Because of the biasing feature, subsequent battle positions were generated progressively closer to the centerline of the AO. During the replication shown in Figure 8, the AH was operating in the AO for 11.126 minutes.

Event SIMEND

Event SIMEND is the logical ending of any replication. Because of this, the event handles most of the statistical bookkeeping, including the calculation of P_k. The approach used was that of assigning a P_k of zero for any replication which generated no impacts close enough to warrant any probability of kill. However, for those instances in which there were at least one impact encounter which warranted P_k consideration, each impact was examined in turn against a random deviate drawn from a uniform (0,1) distribution. If a random deviate was less than or equal to the probability of kill for any single encounter, an AH kill was confirmed and the overall P_k for that replication was set at 1.0. Otherwise, the replication's P_k was set at 0.0. The mean value of the P_k statistic was tallied under the label STAT.1. This average P_k per AH operation in the AO is the output received by experimenting with this model.

Event SIMEND controls when the plotting package, called SUBROUTINE SCRIBE, is executed. The determination of whether the number of replications, as specified by the user, has been completed is also made in this event. If it is determined that at least one more replication of the model is necessary, global variables, which were primarily used as counters, are set to zero before the next replication is begun. Also, any events named THREAT, PREC.FIRE, and/or LOS, which may be waiting for execution in the timing queue, are cancelled and destroyed.

Programs MAIN and SCRIBE

The two main functions of the program MAIN are to allow the user to input the value of certain variables and to initially schedule the occurrence of the events called SCENARIO, THREAT, and LOS.

The subroutine called SCRIBE is written in FORTRAN code and contains the instructions which produced most of the figures contained in this thesis. The user of the model is cautioned that this particular FORTRAN linkage to the basic SIMSCRIPT II.5 model allows for only a one-direction flow of arguments from the calling routine (SIMEND) to the SUBROUTINE SCRIBE. However, the SIMSCRIPT II.5 language does permit the passage of argument values in both directions if the user so desires and the appropriate control cards are inserted.

This completes the detailed explanation of the simulation model. As can be seen from these descriptions, this event-structured model is well matched to the capabilities of the SIMSCRIPT II.5 language.

V. SAMPLE RESULTS

To offer an example of the AH vulnerability calculations that this model provides, a hypothetical artillery threat was created. The curve which relates the P_k versus range to target for this fictitious threat is graphed in Appendix A.

The vulnerability results which are graphed in this chapter are a function of the changing levels of the model's variables called T1, CALL.TO.FIRE, TLE, and C3.DELAY. T1 is the time interval between successive artillery impacts of the simulated area fire, measured in seconds. CALL.TO.FIRE is the number of seconds that the AH must remain in place, after arrival at the initial battle position, prior to commencing a TOW engagement. TLE is the forward observer's target location error, measured in meters. C3.DELAY is the amount of time between the forward observer's detection of the AH and the first impact of the resultant precision fire artillery mission.

Some of the most important background conditions which were in effect when the model was run to obtain the vulnerability data contained in Figures 9, 10 and 11 are listed here.

AO dimension	=	3000 meters by 3000 meters
Nap-of-the-earth maximum angular deviation from beeline ground track	=	45°

Ingress/Egress velocity	=	50 knots
Nap-of-the-earth maximum velocity	=	15 knots
Threat probable error in range	=	125 meters
Threat probable error in deflection	=	30 meters
Precision fire mission rate of fire	=	8 rounds per minute
Ambient light level	=	1000 foot-candles
Time interval between line of sight tests	=	10 seconds
Target-to-background contrast ratio	=	0.3

From Figure 9, it is seen that the model predicts that the AH generally becomes increasingly vulnerable as the AH remains longer at the initial battle position before commencing the first TOW engagement. This is intuitively correct because the smaller CALL.TO.FIRE values mean that the AH, on the average, will be spending less time in the AO conducting its anti-armor mission. Thus, the exposure to the artillery threat is lessened. The results of changing the levels of the parameter T1 from 2 seconds to 11 seconds also appear reasonable. Along the complete range of the CALL.TO.FIRE values plotted, a 31.9% increase in the AH vulnerability is noted for the state T1 = 2 seconds. This compares favorably with the vulnerability increase for state T1 = 11 seconds of 32.4%. The result that state

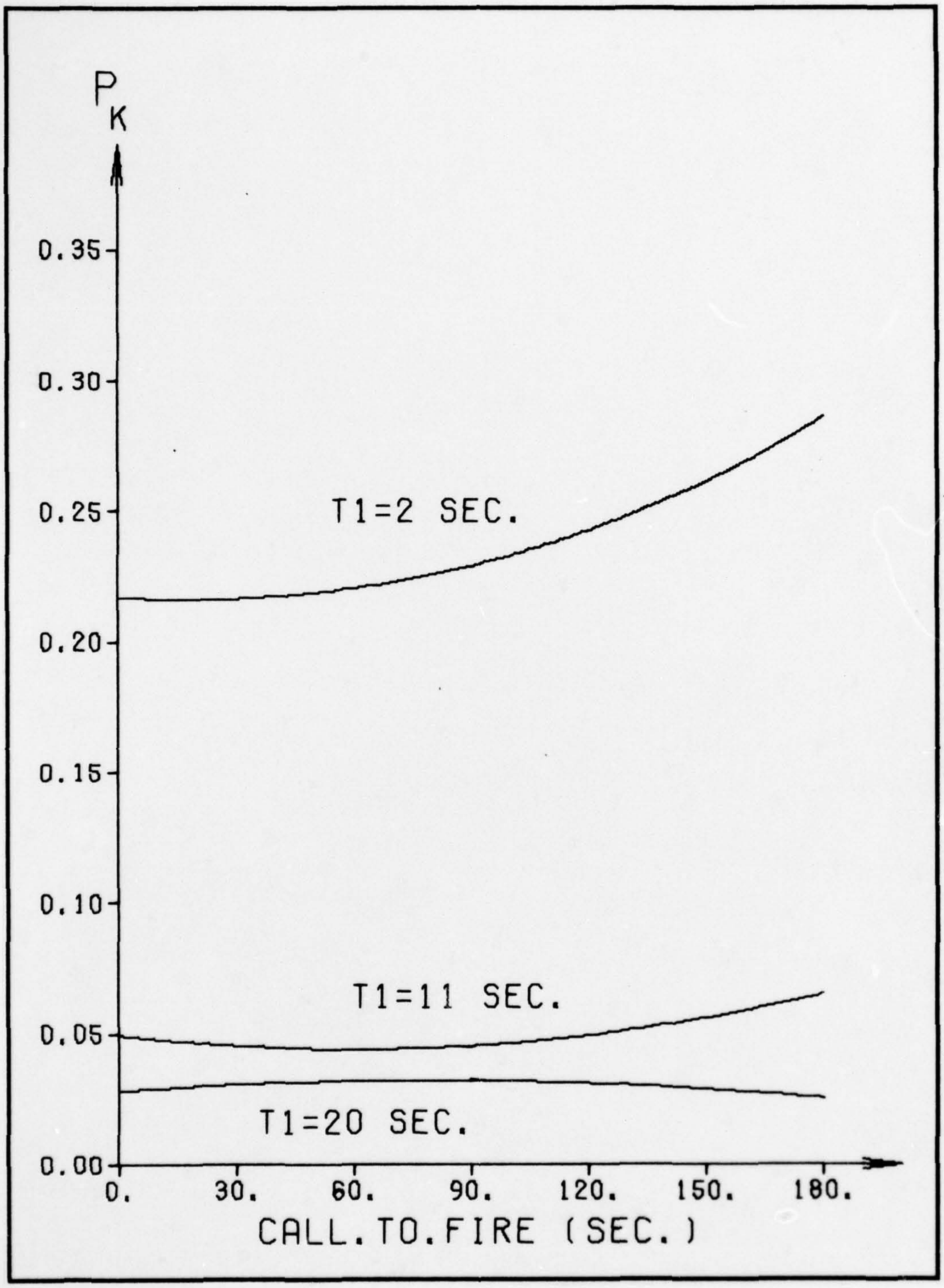


Figure 9. AH Vulnerability to Hypothetical Artillery Threat, Area Fire Only

T1 = 20 seconds appears essentially as a level line is probably a function of the fact that the time between artillery impacts is now getting very large when compared to increasing amounts of time being spent at the initial battle position. Consequently, AH vulnerability is becoming less sensitive to changing levels of the CALL.TO.FIRE parameter at the higher T1 values.

The results of Figure 10 differ from the results of Figure 9 in the increased vulnerability at corresponding states of the environment. This is because Figure 10 contains output from those replications of the model in which a forward observer and precision fire missions were simulated in addition to the area fire missions. Another difference in the results is that the rate of vulnerability increase along the entire range of CALL.TO.FIRE values changes dramatically with the different values of T1. At state T1 = 2 seconds, the vulnerability increase is 37.1%; at state T1 = 11 seconds, the increase is 65.4%; at state T1 = 20 seconds, the increase is 70.1%. This is explained by the fact that, as the intensity of the area fire diminishes (T1 getting larger), the threat to the AH by the precision fire missions becomes a greater part of the total threat. Consequently, longer stays in the AO, which is indicative of increasing CALL.TO.FIRE values, means that the overall AH vulnerability becomes more sensitive to the precision fire encounters than to the area fire encounters. The increased rate of vulnerability shown by

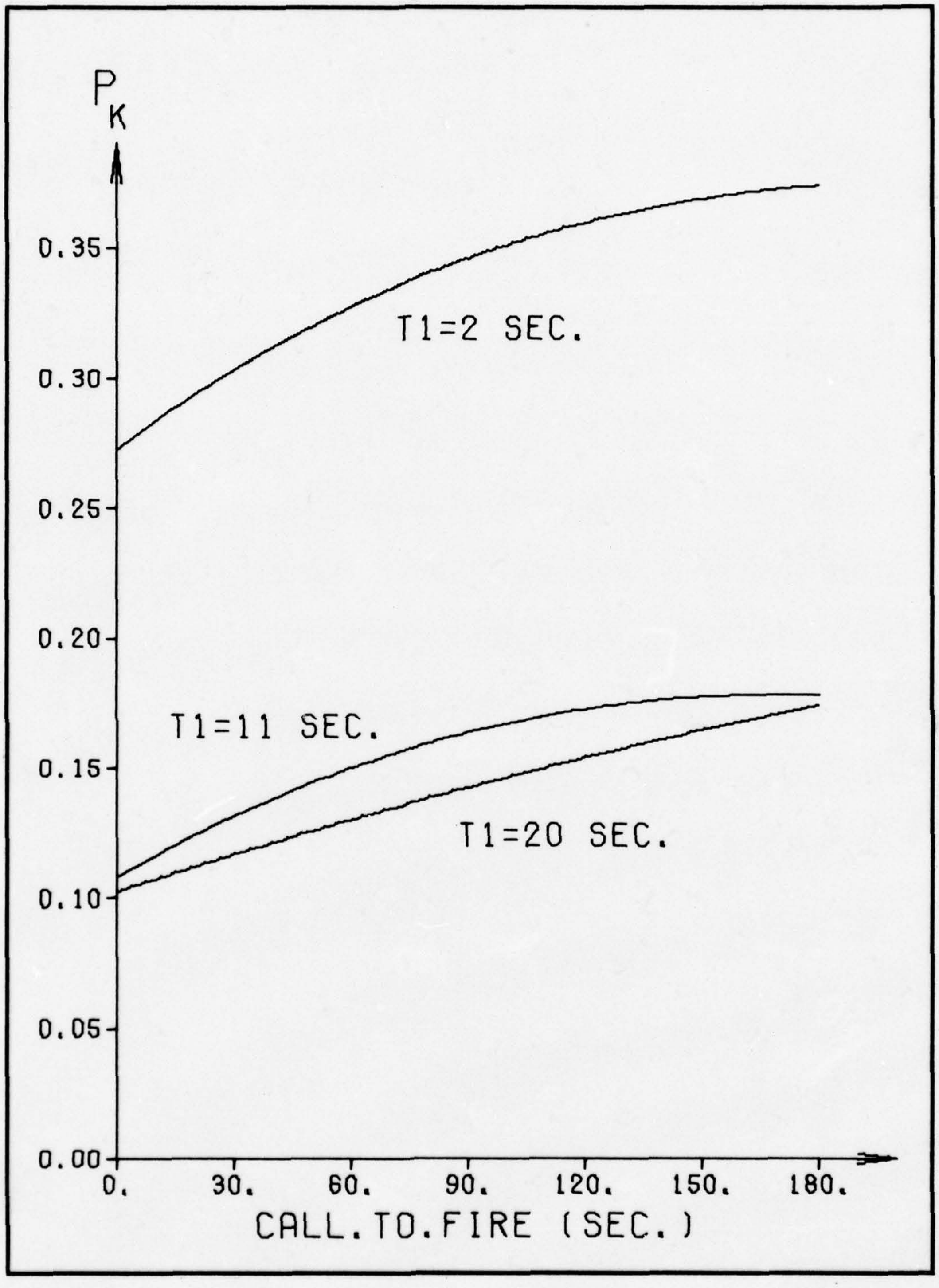


Figure 10. AH Vulnerability to Hypothetical Artillery Threat, Area Fire Plus Precision Fire with C3.DELAY = 60 Seconds and TLE = 50 Meters.

the model is proof of that.

The results of Figure 11 are more difficult to explain. The background conditions for this figure included area fire at five-second intervals while the CALL.TO.FIRE value was held constant at 50 seconds. As shown by the TLE = 10 meters and TLE = 100 meters curves, the model produces the intuitively correct response that increasing forward observer accuracy (TLE getting smaller), the AH vulnerability increases. At once, the TLE = 55 meters curve seems out of place. One answer that can be offered to explain this apparent anomaly is that the replication planning factors applied to this research only give the experimenter a 90% confidence level that the model's output lies within ± 0.03 of the actual P_k for the environment being simulated. Since the TLE = 10 meter and TLE = 55 meter curves are everywhere within a P_k of 0.01 of each other, there remains some possibility that, for all practical purposes, the vulnerability results of Figure 11 are insensitive to changing levels of TLE in the range of 10 meters to 55 meters. Additional experimentation with the model is warranted in order to more completely understand the interaction among variables. Another objective for further experiments might be to determine why two of the curves in Figure 11 are shaped concave upward while the lower curve is concave downward. At any rate, the results of Figure 11 are intuitively correct regarding the C3.DELAY parameter. What the model predicts is that increasing the time delay between target

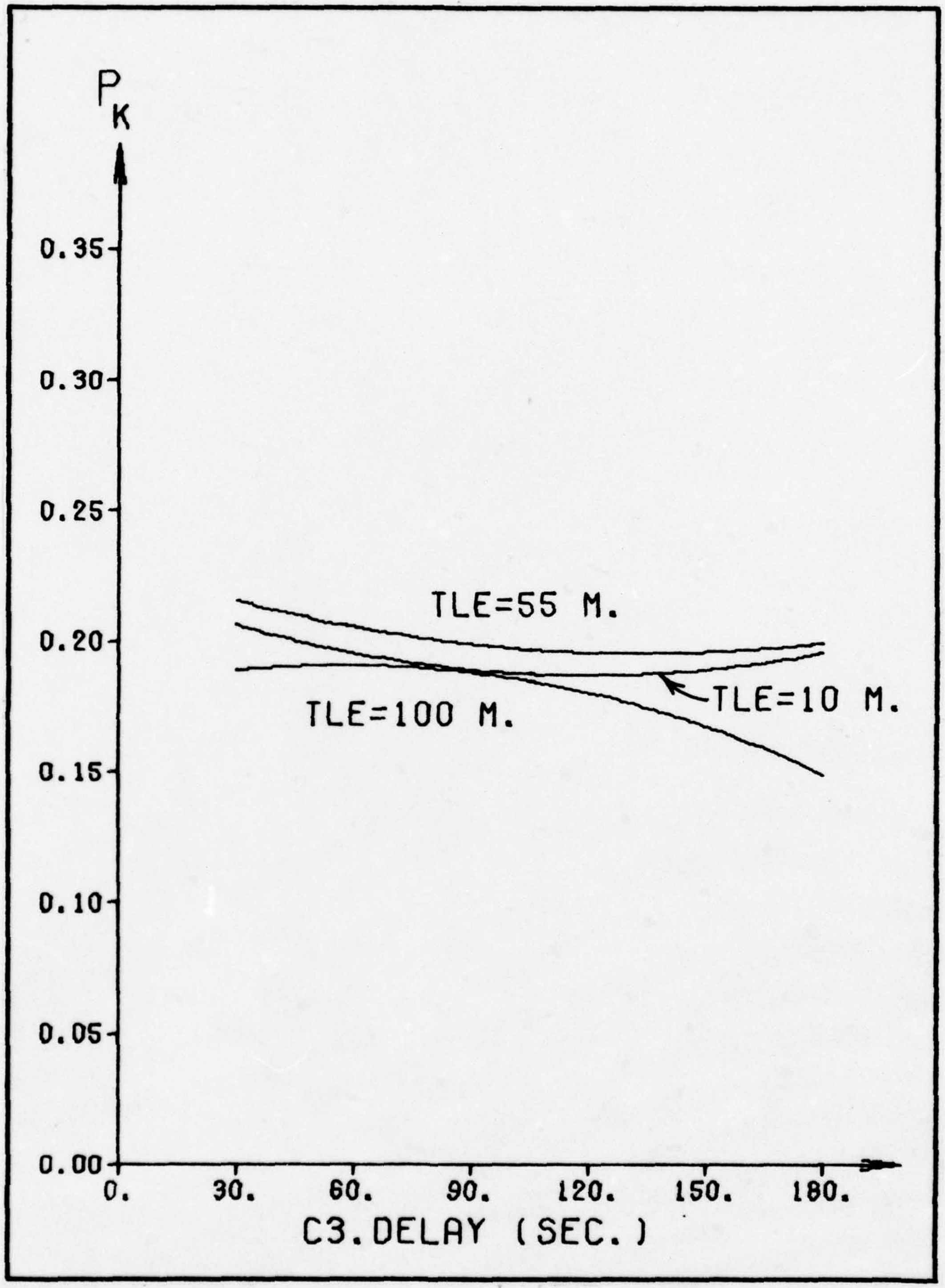


Figure 11. AH Vulnerability to Hypothetical Artillery Threat, Area Fire Plus Precision Fire with T1 = 5 Seconds and CALL.TO.FIRE = 50 Seconds

detection and initiation of the precision fire mission generally decreases the AH vulnerability to the artillery threat.

This chapter was certainly not intended to be an exhaustive example of this model's capabilities. It was, however, meant to show the general form of the model's output. The user of the model, by careful selection of the input parameter values, will be able to examine in detail as much of the artillery versus AH environment that he so desires.

VI. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

This research addressed the problem that very little quantitative information exists which predicts AH vulnerability to hostile artillery fire while the helicopter is being operated near the FEBA. In an attempt to increase the understanding of this battlefield phenomenon, a computer model was developed to simulate this environment and the model was subsequently experimented upon to predict AH vulnerability. The resulting model, with its appropriate assumptions and constraints, is described in this thesis.

Conclusions

Four goals were set at the beginning of this research in order to measure the degree to which this research succeeded in solving the stated problem. These goals will be separately discussed.

The first goal was to construct a computer model. This goal was met by the writing of a computer program that simulates, to the degree specified in the assumptions and constraints, the artillery fire versus AH environment. The detailed description of how the model performs this simulation is contained in Chapter IV.

The second goal was to determine, by internal verification and external validation, that the model behaves

properly. This goal was met by rigorous examination of the model's output in graphical form and from the exchange of ideas between the researcher and experts in the field. These procedures are described in Chapter III.

The third goal was to perform sensitivity analysis upon the main parameters of interest. This goal was met by selecting four parameters and, then, experimenting with the model while using various levels of these parameters. The model's results from this experimentation are included in Chapter V.

The final goal was to draw general conclusions about the AH vulnerability to the artillery threat based upon the model's output. This goal was met by the interpretation of the model's vulnerability predictions. As was discussed in Chapter V, the AH becomes more vulnerable the longer it remains operating in the AO. That vulnerability also increases with increasing intensity of the simulated area fire. The AH also becomes more vulnerable as the forward observer is credited with having better C^3 capability with his supporting artillery unit. The model generally shows that increasing AH vulnerability is also a function of increased forward observer accuracy in specifying the AH's location. All of these predictions were as expected. The fact that the user of this model has numerous variables to specify prior to experimentation makes the forming of definitive conclusions about the model's performance

difficult to make other than in these most general of terms.

Recommendations

As this research effort drew to a close, reflection upon what was accomplished logically led to several ideas which could enhance the realism of this simulation model. These ideas are described in this section.

Currently, the model simulates the TOW engagement sequence as simply a fixed amount of time (35 seconds) that the AH is required to remain at a battle position prior to moving on. This treatment obviously does not capture very much of what actually transpires during this AH activity. One idea for improving this part of the model is to allow the AH to be characterized by some specified height above the ground during the TOW engagement. This additional attribute for the AH is in contrast to the model's current handling of AH position in two dimensions only. This height parameter would then influence the probability that line of sight exists and the probability of detection by the forward observer. The fact that a TOW launch has or has not occurred could become another random variable and the missile launch itself should have some bearing upon the AH's detectability. Another idea is to subject the AH crew to similar line of sight and detection algorithms in the crew's search for the armor target. The effects of modeling this battlefield activity

surely would cascade into the TOW launch versus no-launch concept and into the possibility of whether or not subsequent reattacks are to be made. Also, the present model has constrained the number of TOW engagements per sortie in the AO to a maximum of four. However, since the aircraft is capable of being loaded with eight missiles, the maximum number of TOW engagements available to the AH during any single replication should be increased to eight with, perhaps, different probabilities associated with each weapon load.

At this state of model development, the movement of the AH within the AO is not influenced in any way by the artillery activity. A logical improvement to this is to incorporate decision rules for the simulated AH crew to follow as the crew is given the capability to sample the artillery environment and react to it. These decision rules could be flexible to the extent that the decision logic is adaptive to the urgency of the AH's anti-armor mission. Candidate cues for the AH crew to use in exercising their newly created decision making capability are the proximity of detonating rounds, the frequency with which rounds are detonating in the crew's available field of view, the aspect of the encounter (front, right rear quarter, etc.), and interactions among these three cues. The inclusion of aspect would necessarily require an upgrade to the AH's positional descriptor from two dimension coordinate, as is presently simulated, to two dimension coordinate plus an azimuth reference for the aircraft's

longitudinal axis. The goals of such a modification should be to prevent the AH entry into a region which is experiencing a heavy artillery preparation and to command a hasty departure from such a region should the AH be caught unawares.

At present, only a single gun is modeled during the precision fire artillery missions. A suggestion offered by the Fighter Division, Directorate of Studies and Analyses, Headquarters Air Force is to upgrade this one gun attack to a multiple gun attack by using the concept of Mean Point of Impact (MPI). This methodology essentially takes into account that the central aimpoint of a single weapon, from a battery of weapons, will be randomly distributed about an MPI in a manner analogous to that which is presently used in the Event THREAT by probable errors in range and deflection. After the central aimpoint for each weapon has been specified, the application of individual rounds should proceed as presently formulated.

One final recommendation is for an examination of other measures of AH vulnerability that may be just as appropriate for the model's user as that which is contained in this model. This model specifies AH vulnerability to be the computed P_k per AH sortie within the AO. Other choices for vulnerability may be P_k per unit time and P_k per number of TOW engagements which were attempted. Of the four general recommendations presented in this section, this last recommendation appears to weigh most heavily upon the particular user's preference.

BIBLIOGRAPHY

1. Taylor, John W.R. "Jane's Aerospace Review 1978/79," Air Force Magazine, 62 (1): 26-33 (January 1979).

2. Showan, S.R. Simulation for Tank/Anti-Tank Evaluation (STATE II) Concept and Model Description. Technical Memorandum STC TM-324. The Hague, The Netherlands: SHAPE Technical Centre, May 1972. (AD 901 005).

3. U.S. Army Combat Developments Experimentation Command (USACDEC). Scout Helicopter Artillery Observation. CDEC Experiment 43.8 Phases I & IIB Final Report. Fort Ord, CA: USACDEC, November 1973. (AD 914 773L).

4. Hornung, John P., et al. Automated Fire Support Artillery (AFSA) Model, Volume I, Model Description. CORG Memorandum CORG-M-339. Fort Belvoir, VA: U.S. Army Combat Developments Command, May 1968. (AD 841 361).

5. Sullivan, Capt Jerry. Air Liaison Officer, 6th Air Cavalry Combat Brigade (telephone conversations). Ft. Hood, TX, October 1978 - March 1979.

6. Canedy, Brig Gen Charles E. "TAC Air: An Army View," Air Force Magazine, 61 (2): 56-57 (February 1978).

7. Taylor, John W.R. Jane's All The World's Aircraft. New York: Franklin Watts, Inc., 1978.

8. "Science/Scope," Air Force Magazine, 61 (11): 55 (November 1978).

9. FM 17-50. Attack Helicopter Operations. Washington: Department of the Army, 1 July 1977.

10. FM 17-47. Air Cavalry Combat Brigade. Washington: Department of the Army, 29 April 1977.

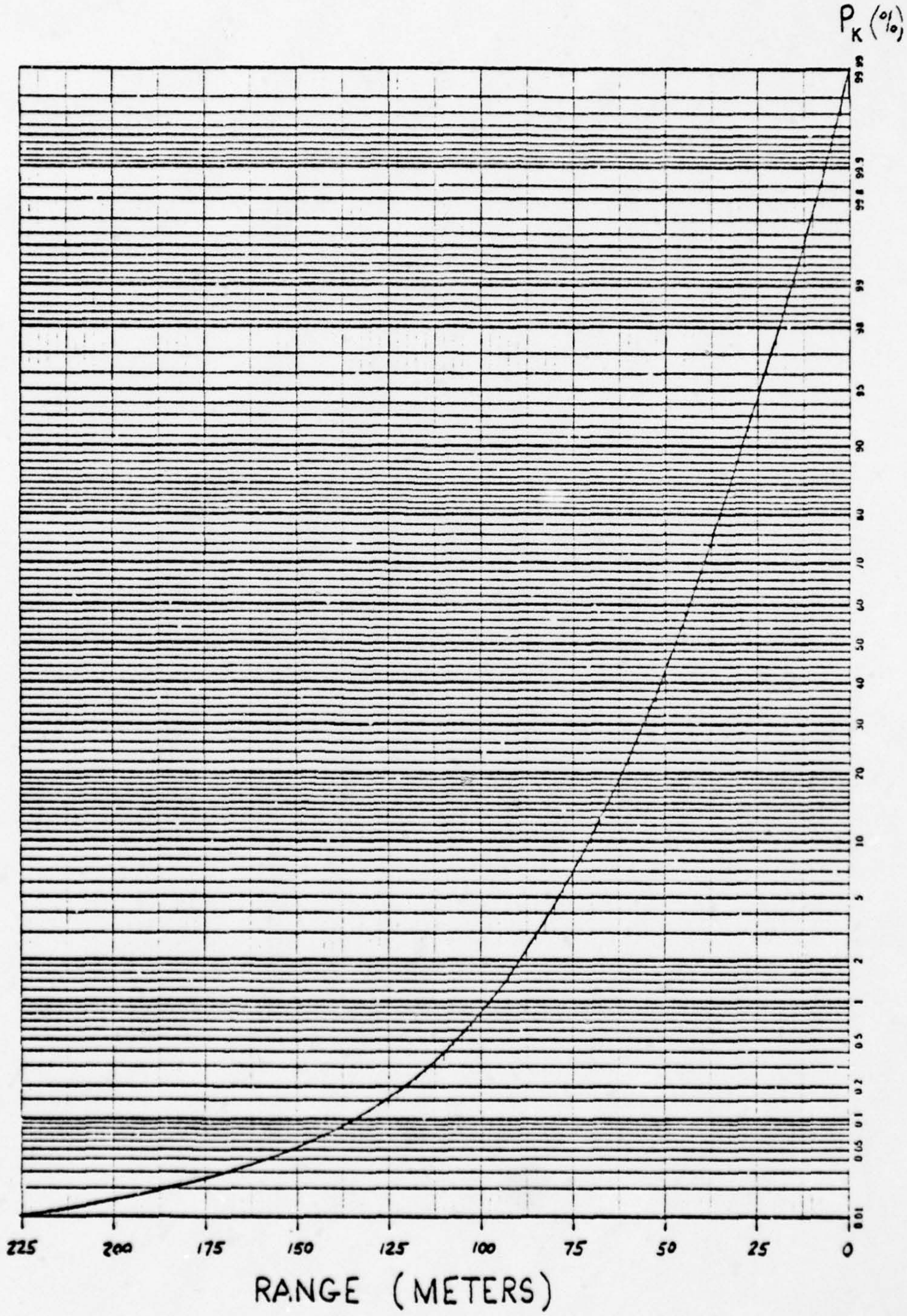
11. FM 90-1. Employment of Army Aviation Units in a High Threat Environment. Washington: Department of the Army, 30 September 1976.

12. Shannon, Robert E. Systems Simulation: The Art and Science. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1975.

APPENDIX A

HYPOTHETICAL THREAT DATA AND CODE LISTING

The first page of this appendix contains the vulnerability curve of the hypothetical artillery weapon as a function of range between AH and burst point of a round. The remaining pages of this appendix contain the code listing for this computer simulation model.


P_K (%)
225
200
175
150
125
100
75
50
25
0
RANGE (METERS)

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JOB CARD
CONTROL CARDS
END OF RECORD CARD

      SUBROUTINE SCRIBE(AHX,AHY,ARTYX,ARTYY,XMAX,YMAX,K,L,J,I1,PKX,PKY,
     CPKS,NRUNS,PER,PED,AIMX,AIMY,IFLAG)
      DIMENSION AHX(1),AHY(1),ARTYX(1),ARTYY(1),PKX(1),PKY(1),PKS(1)
      XC=XMAX/4.5
      YC=YMAX/4.5
      AHX(K+1)=0.     $AHX(K+2)=XC
      AHY(K+1)=0.     $AHY(K+2)=YC
      ARTYX(L+1)=0.  $ARTYX(L+2)=XC
      ARTYY(L+1)=0.  $ARTYY(L+2)=YC
      PKX(I1+1)=0.   $PKX(I1+2)=XC
      PKY(I1+1)=0.   $PKY(I1+2)=YC
      F=FLOAT(J)
      CALL PLOT(0.,-3.,-3)
      CALL PLOT(2.,2.5,-3)
60    CALL SPAXIS(0.,0.,15HX-AXIS (METERS),-15,4.5,0.,0.,XC,1.17,-.5,.15
     C,0.,.75,0,0.)
      CALL SPAXIS(0.,0.,15HY-AXIS (METERS),15,4.5,90.,0.,YC,-.687,1.17,
     C.15,90.,.75,0,0.)
      CALL PLOT(0.,4.5,3)
      CALL PLOT(4.5,4.5,2)
      CALL PLOT(4.5,0.,2)
      CALL PLOT(4.9625,-1.,3)
      CALL PLOT(-1.125,-1.,2)
      CALL PLOT(-1.125,5.5,2)
      CALL PLOT(4.9625,5.5,2)
      CALL PLOT(4.9625,-1.,2)
      CALL PLOT(4.9725,-1.01,3)
      CALL PLOT(-1.136,-1.01,2)
      CALL PLOT(-1.136,5.51,2)
      CALL PLOT(4.9725,5.51,2)
      CALL PLOT(4.9725,-1.01,2)
      CALL SYMBOL(1.125,4.625,.375,3HRUN,0.,3)
      CALL SYMBOL(2.5,4.625,.375,75,0.,-1)
      CALL NUMBER(3.0,4.625,.375,F,0.,-1)
      IF(L40.EQ.8)70,80
80    CALL LINE(AHX,AHY,K,1,0,11)
      IF(I1.GE.1)10,20
10    DO 100 I=1,I1
      X1=PKX(I)/XC+.15
      Y1=PKY(I)/YC-.07
      X2=PKX(I)/XC
      Y2=PKY(I)/YC
      CALL SYMBOL(X2,Y2,.07,0,0.,-1)
      CALL SYMBOL(X1,Y1,.07,2HPK,0.,2)
      CALL SYMBOL(999.,999.,.07,71,0.,-1)
100   CALL NUMBER(999.,999.,.07,PKS(I),0.,6)
20    CALL PLOT(11.,0.,-3)
      L40=8
      GO TO 60
70    CALL LINE(ARTYX,ARTYY,L,1,-1,3)
      IF(IFLAG.EQ.1)71,40
71    A1=(AIMX-1.559*PED)/XC
      A2=(AIMY+1.559*PER)/YC
      B1=(AIMX+1.559*PED)/XC
      B2=A2
      C1=B1
      C2=(AIMY-1.559*PER)/YC
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      D1=A1
      D2=C2
      CALL PLOT(A1,A2,3)
      CALL PLOT(B1,B2,2)
      CALL PLOT(C1,C2,2)
      CALL PLOT(D1,D2,2)
      CALL PLOT(A1,A2,2)
 40   CALL PLOT(11.,0.,-3)
 95   END


END OF RECORD CARD


PREAMBLE
LAST COLUMN IS 80
DEFINE I,J,K,L,A,I1,NO.RUNS,I2,FLAG,FLAG1,FLAG2,FT,OPTION
AS INTEGER VARIABLES
DEFINE X.MAX,Y.MAX,BP.X,BP.Y,ENTRYX,ENTRYY,XSLOWDOWN,YSLOWDOWN,XSPEEDUP,COUNT,
YSPEEDUP,EXIT.X,EXIT.Y,1ALTX,1ALTY,2ALTX,2ALTY,3ALTX,3ALTY,PK1,AIMX,AIMY,
HISPEED,LOSPEED,DEL.T,PHI.MAX,CALL.TO.FIRE,X1,Y1,D.X,D.Y,THETA.I,R.I,T1,PK.STEP,
C3.DELAY,PE.R,PE.D,TLE,ROF,ROUNDS,FOX,FOY,TERRAIN,H,X22,Y22,RNG,AL1,DI,
FO.YLINE                                                      AS REAL VARIABLES
DEFINE AHX,AHY,ARTYX,ARTYY,PK.THREAT,PK.X,PK.Y,PKS,RC            AS 1-DIM ARRAYS
DEFINE IL        AS AN INTEGER,1-DIM ARRAY
DEFINE SCRIBE AS A FORTRAN ROUTINE
EVENT NOTICES INCLUDE NOE,SCENARIO,INGRESS,THREAT,ENTRY.LEG,1.REATTACK,
2.REATTACK,3.REATTACK,DROPBACK,EGRESS,SIMEND,PREC.FIRE,LOS,DETECT
TEMPORARY ENTITIES
EVERY AH HAS SOME X,SOME Y, A TIME, AND BELONGS TO A POSITION
THE SYSTEM OWNS THE POSITION
TALLY STAT.1 AS THE MEAN AND STAT.2 AS THE VARIANCE OF PK1
END


MAIN
RESERVE ARTYX(*),AND ARTYY(*) AS 999,AND PK.X(*),PK.Y(*),AND PKS(') AS 999
RESERVE IL(*),AND RC(*) AS 2
    ''INPUT USER-DESIRED VARIABLES
READ X.MAX,Y.MAX,DEL.T,PHI.MAX,T1,A,PK.STEP,HISPEED,LOSPEED,CALL.TO.FIRE,NO.RUNS
READ C3.DELAY,PE.R,PE.D,TLE,ROF,ROUNDS,FO.YLINE,TERRAIN,H
READ AL1,OPTION
    ''X.MAX,Y.MAX ARE THE AO DIMENSIONS IN METERS
    ''DEL.T IS THE TIME INCREMENT FOR NOE VELOCITY VECTOR IN SECONDS
    ''PHI.MAX IS THE MAX ANGULAR DEFLECTION OF THE VELOCITY VECTOR IN DEGREES
    ''T1 IS THE ARTY FIRING INTERVAL IN SECONDS
    ''A IS THE NUMBER OF PK DATA POINTS TO BE ENTERED
    ''PK.STEP IS THE RANGE BETWEEN EACH SUCCESSIVE PK DATA POINT IN METERS
    ''NO.RUNS IS THE DESIRED NUMBER OF REPLICATIONS FOR THIS SINGLE JOB
    ''HISPEED IS THE VELOCITY USED DURING INGRESS/EGRESS IN KNOTS
    ''LOSPEED IS THE UPPER BOUND VELOCITY FOR NOE FLIGHT IN KNOTS
    ''CALL.TO.FIRE IS THE TIME DELAY AFTER ARRIVAL AT THE INITIAL BATTLE
    ''POSITION PRIOR TO THE UNMASK MANEUVER IN SECONDS
    ''C3.DELAY IS TIME LOST, DETECTION TO 1ST ROUND, IN MINUTES
    ''PE.R IS PROBABLE ERROR IN RANGE (METERS)
    ''PE.D IS PROBABLE ERROR IN DEFLECTION (METERS)
    ''TLE IS TARGET LOCATION ERROR IN METERS
    ''ROF IS SINGLE GUN RATE OF FIRE IN ROUNDS PER MINUTE
    ''ROUNDS IS TOTAL AMOUNT OF ROUNDS TO BE EXPENDED DURING PRECISION FIRE
    ''FO.YLINE IS DISTANCE ABOVE TOP OF AO OF THE FO POSITION IN METERS
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    ''TERRAIN IS THE TERRAIN TYPE COEFFICIENT
    ''H IS THE FO'S VIEWING HEIGHT AGL IN METERS
    ''AL1 IS THE TARGET ILLUMINATION IN FOOT-CANDLES
    ''IF OPTION=1 PREC FIRE IS CONDUCTED. OPTION=0 AREA FIRE ONLY.
PRINT 9 LINES WITH X.MAX,Y.MAX,DEL.T,PHI.MAX,T1,HISPEED,LOSPEED,CALL.TO.FIRE,
NO.RUNS AS FOLLOWS
              ##### USER HAS INPUT THE FOLLOWING PARAMETERS #####
        AO DIMENSIONS ARE ****. METERS BY ****. METERS
        NOE DISPLACEMENT STEPS ARE TAKEN AT **.-SECOND INTERVALS
        MAX ANGULAR DEVIATION FROM BEE-LINE PATH IS **. DEGREES
        ARTILLERY IS IMPACTING AT **.-SECOND INTERVALS
        INGRESS/EGRESS AH VELOCITY IS ***. KNOTS
        NOE MAX SPEED LIMITED TO **. KNOTS
        AT INITIAL BP, ***. SECONDS OF DELAY IS DIRECTED PRIOR TO UNMASK
        ***. REPLICATIONS ARE DESIRED
PRINT 9 LINES WITH C3.DELAY,PE.R,PE.D,TLE,ROF,ROUNDS,FO.YLINE,TERRAIN,H AS
FOLLOWS
        C-CUBED DELAY IS *.* MINUTES
        PROBABLE ERROR IN RANGE IS ***. METERS
        PROBABLE ERROR IN DEFLECTION IS ***. METERS
        TARGET LOCATION ERROR IS ***. METERS
        SINGLE WEAPON RATE OF FIRE IS **.* ROUNDS PER MINUTE
        TOTAL ROUNDS PROVIDED FOR THIS MISSION IS ***.
        FO IS RANDOMLY LOCATED ALONG A LINE ****.M FROM THE TOP OF THE AO
        THE TERRAIN TYPE COEFFICIENT IS *.*
        THE OBSERVER'S ALTITUDE IS **. METERS AGL
PRINT 2 LINES WITH AL1,OPTION AS FOLLOWS
        THE ILLUMINATION AT THE TGT IS ****.***** FOOT-CANDLES
        THE PRECISION FIRE OPTION IS *
RESERVE RC,IL AS 2
RESERVE PK.THREAT AS A
READ PK.THREAT
READ FT
IF FT EQ 1,
LET PK.STEP=PK.STEP*0.3048  ''CONVERTS ENTERED DATA FROM FEET TO METERS.
ALWAYS
LET DEL.T=DEL.T/60.
LET T1=T1/60.
LET LOSPEED=LOSPEED*.51444
LET HISPEED=HISPEED*.51444
LET PHI.MAX=PHI.MAX/RADIAN.C
LET J=1
SCHEDULE A SCENARIO NOW
SCHEDULE A THREAT IN UNIFORM.F(0.0,T1,5) MINUTES
IF OPTION EQ 1,
SCHEDULE AN LOS IN 1./6. MINUTES
ALWAYS
START SIMULATION
END


EVENT SCENARIO
LET I=I+1
IF I=1,SCHEDULE AN INGRESS NOW
ALWAYS
IF I=2,SCHEDULE A 1.REATTACK IN (CALL.TO.FIRE+35.)/60. MINUTES
ALWAYS
IF I=3,SCHEDULE A 2.REATTACK IN 35./60. MINUTES
ALWAYS
IF I=4,SCHEDULE A 3.REATTACK IN 35./60. MINUTES
ALWAYS
IF I=5 AND I2=0,SCHEDULE A DROPBACK IN (CALL.TO.FIRE+35.)/60. MINUTES
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ALWAYS
IF I=5 AND I2 NE 0,SCHEDULE A DROPBACK IN 35./60. MINUTES
ALWAYS
IF I=6,SCHEDULE AN EGRESS IN R.I/HISPEED/60. MINUTES
ALWAYS
RETURN
END


EVENT INGRESS    ''TO DETERMINE THE PARTICULAR SCENARIO OF THIS RUN
LET BP.X=UNIFORM.F(0.0,X.MAX,1)
LET BP.Y=UNIFORM.F(Y.MAX-700.,Y.MAX,1)
LET ENTRYX=UNIFORM.F(0.0,X.MAX,1)
LET ENTRYY=0.0
LET FOX=UNIFORM.F(0.0,X.MAX,1)
LET FOY=Y.MAX+FO.YLINE
LET YSLOWDOWN=Y.MAX-1000.
    ''FROM SIMILAR TRIANGLES....
LET XSLOWDOWN=ENTRYX-(ENTRYX-BP.X)*YSLOWDOWN/BP.Y
    ''THROW THE DICE TO DETERMINE THE NUMBER OF REATTACKS TO ACCOMPLISH, IF ANY.
LET YSPEEDUP=YSLOWDOWN
LET EXIT.Y=0.0
LET I2=RANDI.F(0,3,2)
IF I2=0,LET I=4
LET XSPEEDUP=BP.X
LET EXIT.X=BP.X
ALWAYS
    ''BIAS ALL SUBSEQUENT RE-ATTACKS, IF ANY, TO THE CENTER OF THE AO.
IF BP.X LT X.MAX/2.,LET BIAS=1.
ELSE
LET BIAS=-1.
ALWAYS
    ''SUBSEQUENT RE-ATTACKS ARE ALLOWED TO VARY FROM THE PREVIOUS ATTACKING
    ''POSITION BY + OR - 50 METERS IN THE Y COORDINATE AND UNIFORMLY
    ''VARYING FROM 30 METERS TO 150 METERS IN LATERAL DISPLACEMENT.
IF I2=1,LET 1ALTY=UNIFORM.F(BP.Y-50.,BP.Y+50.,1)
IF 1ALTY GT Y.MAX,LET 1ALTY=Y.MAX
ALWAYS
LET 1ALTX=BP.X+BIAS*UNIFORM.F(30.,150.,1)
LET XSPEEDUP=1ALTX
LET EXIT.X=1ALTX
ALWAYS
IF I2=2,LET 1ALTY=UNIFORM.F(BP.Y-50.,BP.Y+50.,1)
IF 1ALTY GT Y.MAX,LET 1ALTY=Y.MAX
ALWAYS
LET 1ALTX=BP.X+BIAS*UNIFORM.F(30.,150.,1)
LET 2ALTY=UNIFORM.F(1ALTY-50.,1ALTY+50.,1)
IF 2ALTY GT Y.MAX,LET 2ALTY=Y.MAX
ALWAYS
LET 2ALTX=1ALTX+BIAS*UNIFORM.F(30.,150.,1)
LET XSPEEDUP=2ALTX
LET EXIT.X=2ALTX
ALWAYS
IF I2=3,LET 1ALTY=UNIFORM.F(BP.Y-50.,BP.Y+50.,1)
IF 1ALTY GT Y.MAX,LET 1ALTY=Y.MAX
ALWAYS
LET 1ALTX=BP.X+BIAS*UNIFORM.F(30.,150.,1)
LET 2ALTY=UNIFORM.F(1ALTY-50.,1ALTY+50.,1)
IF 2ALTY GT Y.MAX,LET 2ALTY=Y.MAX
ALWAYS
LET 2ALTX=1ALTX+BIAS*UNIFORM.F(30.,150.,1)
LET 3ALTY=UNIFORM.F(2ALTY-50.,2ALTY+50.,1)
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IF 3ALTY GT Y.MAX,LET 3ALTY=Y.MAX
ALWAYS
LET 3ALTX=2ALTX+BIAS*UNIFORM.F(30.,150.,1)
LET XSPEEDUP=3ALTX
LET EXIT.X=3ALTX
ALWAYS
LET D.X=XSLOWDOWN
LET D.Y=YSLOWDOWN
    ''INITIALIZE THE AH POSITION AT THE ENTRY POINT TO THE AO
CREATE AN AH
LET X=ENTRYX
LET Y=0.0
LET X1=X
LET Y1=Y
LET TIME=TIME.V*1440.
FILE THIS AH IN POSITION
LET R.I=SQRT.F((ENTRYX-XSLOWDOWN)**2+YSLOWDOWN**2)
LET THETA.I=0.0
SCHEDULE AN ENTRY.LEG IN R.I/HISPEED/60. MINUTES
RETURN
END

EVENT ENTRY.LEG    ''EMPLOYS STRAIGHT LINE FLIGHT
CREATE AN AH
LET X=D.X
LET Y=D.Y
LET X1=X
LET Y1=Y
LET TIME=TIME.V*1440.
FILE THIS AH IN POSITION
LET D.X=BP.X
LET D.Y=BP.Y
LET R.I=DEL.T*60.*UNIFORM.F(.5*LOSPEED,LOSPEED,4)
LET THETA.I=UNIFORM.F(-1.*PHI.MAX,PHI.MAX,4)
SCHEDULE AN NOE NOW
RETURN
END

EVENT 1.REATTACK
LET D.X=1ALTX
LET D.Y=1ALTY
LET R.I=DEL.T*60.*UNIFORM.F(.5*LOSPEED,LOSPEED,4)
IF I2=1,LET I=4
ALWAYS
SCHEDULE AN NOE NOW
RETURN
END

EVENT 2.REATTACK
LET D.X=2ALTX
LET D.Y=2ALTY
LET R.I=DEL.T*60.*UNIFORM.F(.5*LOSPEED,LOSPEED,4)
IF I2=2,LET I=4
ALWAYS
SCHEDULE AN NOE NOW
RETURN
END
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EVENT 3.REATTACK
LET D.X=3ALTX
LET D.Y=3ALTY
LET R.I=DEL.T*60.*UNIFORM.F(.5*LOSPEED,LOSPEED,4)
SCHEDULE AN NOE NOW
RETURN
END


EVENT DROPBACK
LET D.X=XSPEEDUP
LET D.Y=YSPEEDUP
LET R.I=DEL.T*60.*UNIFORM.F(.5*LOSPEED,LOSPEED,4)
SCHEDULE AN NOE NOW
RETURN
END


EVENT EGRESS   ''EMPLOYS STRAIGHT LINE FLIGHT
CREATE AN AH
LET X=D.X
LET Y=D.Y
LET TIME=TIME.V*1440.
FILE THIS AH IN POSITION
SCHEDULE A SIMEND NOW
RETURN
END


EVENT NOE
    ''SIMULATES NAP OF THE EARTH FLIGHT BY GENERATING A SUCCESSION OF SHORT,
    ''STRAIGHT POSITION VECTORS OF VARYING LENGTH AND VARYING ANGULAR
    ''DISPLACEMENT FROM THE BEE-LINE ORIENTATION.
CREATE AN AH
LET TIME=TIME.V*1440.
LET RANGE=SQRT.F((D.X-X1)**2+(D.Y-Y1)**2)
IF RANGE LE R.I, LET X=D.X
LET Y=D.Y
LET X1=X
LET Y1=Y
FILE THIS AH IN POSITION
LET R.I=0.0
IF I=5,LET D.X=XSPEEDUP
LET D.Y=0.0
LET R.I=YSPEEDUP
LET THETA.I=0.0
ALWAYS
SCHEDULE A SCENARIO NOW
GO TO CHECK
ELSE
LET X1=X1+(R.I*COS.F(THETA.I)*(D.X-X1)+R.I*SIN.F(THETA.I)*(Y1-D.Y))/RANGE
LET Y1=Y1+(R.I*COS.F(THETA.I)*(D.Y-Y1)+R.I*SIN.F(THETA.I)*(D.X-X1))/RANGE
    ''THESE INSTRUCTIONS INSURE THAT THE AH REMAINS WITHIN THE AO.
IF X1 LT 0.0,LET X1=0.0
ALWAYS
IF X1 GT X.MAX,LET X1=X.MAX
ALWAYS
IF Y1 LT 0.0,LET Y1=0.0
ALWAYS
IF Y1 GT Y.MAX,LET Y1=Y.MAX
ALWAYS
LET X=X1
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```
LET Y=Y1
FILE THIS AH IN POSITION
LET R.I=DEL.T*60.*UNIFORM.F(.5*LOSPEED,LOSPEED,4)
LET THETA.I=UNIFORM.F(-1.*PHI.MAX,PHI.MAX,4)
SCHEDULE AN NOE IN DEL.T MINUTES
'CHECK' RETURN
END


EVENT LOS     ''THIS EVENT IS SCHEDULED AT 10 SECOND INTERVALS THROUGHOUT THE
              ''LENGTH OF THE SIMULATION.  THE ACTIVITIES WITHIN THIS EVENT
              ''DETERMINE WHETHER OR NOT LINE-OF-SIGHT EXISTS.
IF R.I EQ 0.0,LET X2=X1
LET Y2=Y1
GO TO CHECK
ELSE
IF R.I GT DEL.T*60.*LOSPEED,LET D=R.I/HISPEED/60.
ELSE
LET D=DEL.T
ALWAYS
     ''THIS NEXT SECTION PINPOINTS THE AH LOCATION WHEN THE AH IS IN MOTION AND
     ''ARTY ROUNDS IMPACT DURING THE EXECUTION OF THE AH DISCRETE DISPLACEMENT
     ''STEP.
FOR EACH AH IN POSITION IN REVERSE ORDER, FIND THE FIRST CASE
LET PART.MOVE=(TIME.V*1440.-TIME)/D
LET RANGE=SQRT.F((D.X-X1)**2+(D.Y-Y1)**2)
IF RANGE LE R.I, LET X2=X1+(D.X-X1)*PART.MOVE
LET Y2=Y1+(D.Y-Y1)*PART.MOVE
GO TO CHECK
ELSE
LET X3=X1+(R.I*COS.F(THETA.I)*(D.X-X1)+R.I*SIN.F(THETA.I)*(Y1-D.Y))/RANGE
LET Y3=Y1+(R.I*COS.F(THETA.I)*(D.Y-Y1)+R.I*SIN.F(THETA.I)*(D.X-X1))/RANGE
IF X3 LT 0.0,LET X3=0.0
ALWAYS
IF X3 GT X.MAX,LET X3=X.MAX
ALWAYS
IF Y3 LT 0.0,LET Y3=0.0
ALWAYS
IF Y3 GT Y.MAX,LET Y3=Y.MAX
ALWAYS
LET X2=X1+(X3-X1)*PART.MOVE
LET Y2=Y1+(Y3-Y1)*PART.MOVE
'CHECK' LET RANGE=.001*SQRT.F((FOX-X2)**2+(FOY-Y2)**2)
LET RBAR=TERRAIN*(1.56+3.48*((H/100.)**1.173))
LET PLOS=(2.*RANGE/RBAR+1.)*EXP.F(-2.*RANGE/RBAR)
LET DICE=UNIFORM.F(0.0,1.0,10)
IF DICE GT PLOS,SCHEDULE AN LOS IN 1./6. MINUTES
ELSE
LET X22=X2
LET Y22=Y2
LET RNG=RANGE
SCHEDULE A DETECT NOW
ALWAYS
RETURN
END


EVENT DETECT     ''ONLY ENTERED IF LINE-OF-SIGHT EXISTS.
DEFINE I1,LIGHT AS INTEGER VARIABLES
LET AJOB=2.5
LET ATTN=0.558       ''THIS ATMOSPHERIC ATTENUATION COEFF IS FOR 7 KM VISIBILITY.
LET DIM=4.12
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LET ACON=0.3   ''THIS IS THE TGT/BACKGROUND CONTRAST RATIO.
               ''THE ACON VALUE, TO A GREAT EXTENT, DRIVES THE RESULTS OF THIS
               ''ALGORITHM. INCREASING ACON INCREASES PROB OF DETECTION.
LET TBAR=100000.
LET AL=AL1
LET SOG=3.0        ''THIS PARAMETER IS THE SKY BRIGHTNESS/GROUND BRIGHTNESS RATIO
LET R=RNG*1000.
LET C=ACON/(1.+SOG*(EXP.F(ATTN*R/1000.)-1.))
LET AL=AL*0.7
IF AL LT 100.,GO TO A30
ELSE
LET IL1=1
LET IL2=1
LET ACK=100.
LET AL=100.
GO TO A70
'A30'  IF AL GT .0001,GO TO A40
ELSE
LET PAJOB=0.0
LET TBAR=100000.
GO TO A600
'A40'  LET ACK=100.
FOR I1=1 TO 6,DO
LET IL1=I1
IF AL LE ACK AND AL GE ACK/10.,GO TO A60
ELSE
LET ACK=ACK/10.
LOOP
'A60'  LET IL2=IL1+1
'A70'  LET IL(1)=IL1
LET IL(2)=IL2
LET RC(1)=0.0
LET RC(2)=0.0
FOR I1=1 TO 2,DO
LET LIGHT=IL(I1)
IF LIGHT EQ 1,GO TO B10
ELSE
IF LIGHT EQ 2,GO TO B40
ELSE
IF LIGHT EQ 3,GO TO B70
ELSE
IF LIGHT EQ 4,GO TO B90
ELSE
IF LIGHT EQ 5,GO TO B110
ELSE
IF LIGHT EQ 6,GO TO B130
ELSE
IF LIGHT EQ 7,GO TO B150
ELSE
'B10'  LET RC(I1)=2.74
IF C GT 0.8,GO TO B170
ELSE
IF C LE 0.25,GO TO B20
ELSE
LET RC(I1)=2.8839221*(C**0.2291015)
GO TO B170
'B20'  IF C LT 0.025,GO TO B30
ELSE
LET RC(I1)=2.3365166-0.0509533/C
GO TO B170
'B30'  LET RC(I1)=0.0
GO TO B170
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'B40'  LET RC(I1)=2.74
IF C GT 0.8,GO TO B170
ELSE
IF C LT 0.35,GO TO B50
ELSE
LET RC(I1)=2.8667792*(C**0.2251284)
GO TO B170
'B50'  IF C LT 0.025,GO TO B60
ELSE
LET RC(I1)=2.3262999-0.0514585/C
GO TO B170
'B60'  LET RC(I1)=0.0
GO TO B170
'B70'  LET RC(I1)=2.29
IF C GT 0.7,GO TO B170
ELSE
IF C LT 0.03,GO TO B80
ELSE
LET RC(I1)=C/(0.0497605+0.3579996*C)
GO TO B170
'B80'  LET RC(I1)=0.0
GO TO B170
'B90'  LET RC(I1)=1.8
IF C GT 0.7,GO TO B170
ELSE
IF C LT 0.05,GO TO B100
ELSE
LET RC(I1)=1.6149345-0.0651033/C
GO TO B170
'B100'  LET RC(I1)=0.0
GO TO B170
'B110'  LET RC(I1)=1.32
IF C GT 0.8,GO TO B170
ELSE
IF C LT 0.084,GO TO B120
ELSE
LET RC(I1)=1.336422-0.1123916/C
GO TO B170
'B120'  LET RC(I1)=0.0
GO TO B170
'B130'  LET RC(I1)=0.47
IF C GT 0.8,GO TO B170
ELSE
IF C LT 0.18,GO TO B140
ELSE
LET RC(I1)=0.5686696-0.0968436/C
GO TO B170
'B140'  LET RC(I1)=0.0
GO TO B170
'B150'  LET RC(I1)=0.14
IF C GT 0.8,GO TO B170
ELSE
IF C LE 0.5,GO TO B160
ELSE
LET RC(I1)=0.29-0.12/C
GO TO B170
'B160'  LET RC(I1)=0.0
'B170'  LOOP
LET RC1=RC(1)
LET RC2=RC(2)
LET RX=RC2+(RC1-RC2)*((AL-ACK/10.)/(ACK-ACK/10.))
LET RX=RX*7.0
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LET S=DIM/(R/1000.)
LET RX=RX*S
IF RX LT 0.1,LET RX=0.0
LET PAJOB=0.0
LET TBAR=100000.
GO TO A600
ELSE
LET XX=(RX-AJOB)/(0.625*AJOB)
IF XX GT -45.0,GO TO C10
ELSE
LET PAJOB=0.0
GO TO A500
'C10'  IF XX LT 45.0,GO TO C20
ELSE
LET PAJOB=1.0
GO TO A500
'C20'  LET F=1.0
IF XX LT 0.0,LET F=0.0
ALWAYS
LET S2=XX/1.414
LET X2=ABS.F(S2)
LET E1=1.+(0.0000430638*X2+0.0002765672)*X2**5
LET E1=E1+(0.0001520134*X2+0.0092705272)*X2**3
LET E1=E1+(0.0422820123*X2+0.0705230784)*X2
LET E1=E1**16
LET E1=1.-1./E1
LET PAJOB=0.5+E1/2.
IF F GT 0.0,GO TO A500
ELSE
LET PAJOB=1.-PAJOB
'A500'  LET TS=1.7*600./64.
LET PS=1.-EXP.F(-1.7*RX/8.)
IF PS GT 0.0,GO TO A160
ELSE
LET TBAR=100000.
GO TO A600
'A160'  LET TBAR=0.5*TS*(2.-PS)/PS
'A600'  LET P10=PAJOB*(1.-EXP.F(-10./TBAR))
LET DICE=UNIFORM.F(0.0,1.0,10)
IF DICE GT P10,SCHEDULE AN LOS IN 1./6. MINUTES
ELSE
LET FLAG1=1
LET FLAG2=1
SCHEDULE A PREC.FIRE NOW
ALWAYS
RETURN
END


EVENT PREC.FIRE    ''THIS EVENT CONTROLS THE EMPLOYMENT OF A FO-DIRECTED FIRE
                   ''MISSION AGAINST A POINT TARGET.
IF FLAG1=1,LET FLAG1=0
LET BETA=UNIFORM.F(0.0,2.*PI.C,8)
LET RHO=TLE*SQRT.F(UNIFORM.F(0.0,1.0,7))
      ''FROM THE GEOMETRY OF THE PROBLEM
LET AIMX=X22+RHO*COS.F(BETA)
LET AIMY=Y22+RHO*SIN.F(BETA)
LET FLAG=1
LET COUNT=1
SCHEDULE A THREAT IN C3.DELAY MINUTES
ELSE
IF COUNT LT ROUNDS,LET COUNT=COUNT+1.0
```

```
LET FLAG=1
SCHEDULE A THREAT IN 1.0/ROF MINUTES
ELSE
LET COUNT=0.0
SCHEDULE AN LOS NOW
ALWAYS
ALWAYS
RETURN
END


EVENT THREAT
     ''THIS EVENT LAYS DOWN A UNIFORM BARRAGE PATTERN WITHIN THE AO.
     ''IF REQUIRED, THIS EVENT ALSO LAYS DOWN THE PRECISION FIRING PATTERN
     ''IT ALSO TESTS THE PROXIMITY OF THE AH TO THE ARTY IMPACT AND IF WITHIN
     ''THE IMPACT THREAT ENVELOPE, CALCULATES AND STORES THE APPROPRIATE P-K DATA
DEFINE INDEX AS AN INTEGER VARIABLE
LET L=L+1
IF FLAG EQ 1,LET FLAG=0
LET ARTYX(L)=AIMX+NORMAL.F(0.0,PE.D/0.6745,6)
LET ARTYY(L)=AIMY+NORMAL.F(0.0,PE.R/0.6745,9)
SCHEDULE A PREC.FIRE NOW
GO TO JOB
ELSE
LET ARTYX(L)=UNIFORM.F(0.0,X.MAX,5)
LET ARTYY(L)=UNIFORM.F(0.0,Y.MAX,5)
SCHEDULE A THREAT IN T1 MINUTES
'JOB'
     ''THROUGHOUT, COORDINATE (X1,Y1) ARE THE AH CURRENT POSITION, OR FOR THE AH
     ''IN MOTION, THE MOST RECENTLY OCCUPIED POSITION AMONGST THE SERIES OF
     ''DISCRETE DISPLACEMENT STEPS.
IF R.I EQ 0.0,LET X2=X1
LET Y2=Y1
GO TO CHECK
ELSE
IF R.I GT DEL.T*60.*LOSPEED,LET D=R.I/HISPEED/60.
ELSE
LET D=DEL.T
ALWAYS
     ''THIS NEXT SECTION PINPOINTS THE AH LOCATION WHEN THE AH IS IN MOTION AND
     ''ARTY ROUNDS IMPACT DURING THE EXECUTION OF THE AH DISCRETE DISPLACEMENT
     ''STEP.
FOR EACH AH IN POSITION IN REVERSE ORDER, FIND THE FIRST CASE
LET PART.MOVE=(TIME.V*1440.-TIME)/D
LET RANGE=SQRT.F((D.X-X1)**2+(D.Y-Y1)**2)
IF RANGE LE R.I, LET X2=X1+(D.X-X1)*PART.MOVE
LET Y2=Y1+(D.Y-Y1)*PART.MOVE
GO TO CHECK
ELSE
LET X3=X1+(R.I*COS.F(THETA.I)*(D.X-X1)+R.I*SIN.F(THETA.I)*(Y1-D.Y))/RANGE
LET Y3=Y1+(R.I*COS.F(THETA.I)*(D.Y-Y1)+R.I*SIN.F(THETA.I)*(D.X-X1))/RANGE
IF X3 LT 0.0,LET X3=0.0
ALWAYS
IF X3 GT X.MAX,LET X3=X.MAX
ALWAYS
IF Y3 LT 0.0,LET Y3=0.0
ALWAYS
IF Y3 GT Y.MAX,LET Y3=Y.MAX
ALWAYS
LET X2=X1+(X3-X1)*PART.MOVE
LET Y2=Y1+(Y3-Y1)*PART.MOVE
'CHECK' LET RANGE=SQRT.F((ARTYX(L)-X2)**2+(ARTYY(L)-Y2)**2)
```

```
IF RANGE LT (A-1.)*PK.STEP,LET INDEX=TRUNC.F(RANGE/PK.STEP)
LET I1=I1+1
LET C=RANGE-INDEX*PK.STEP
LET PK=PK.THREAT(INDEX+2)+(1.-C/PK.STEP)*(PK.THREAT(INDEX+1)-PK.THREAT(INDEX+2))
LET PK.X(I1)=ARTYX(L)
LET PK.Y(I1)=ARTYY(L)
LET PKS(I1)=PK
ALWAYS
RETURN
END


EVENT SIMEND
DEFINE G AS AN INTEGER VARIABLE
IF I1 EQ 0,
LET PK1=0.0
ALWAYS
IF I1 GE 1,
FOR G=1 TO I1,DO
     ''THIS DO-LOOP CHECKS THE MONTE CARLO TEST OF THE P-K.
LET DICE=UNIFORM.F(0.0,1.0,10)
IF PKS(G) GE DICE,
LET PK1=1.0
GO TO CHECK
ELSE
IF G=I1,LET PK1=0.0
ALWAYS
LOOP
'CHECK'
ALWAYS
RESERVE AHX(*), AND AHY(*) AS N.POSITION+2
FOR EACH AH IN POSITION,DO
LET K=K+1
LET AHX(K)=X
LET AHY(K)=Y
LOOP
IF J=1,
     ''WITH THIS LOGICAL IF STATEMENT, USER MAY SPECIFY WHICH RUN OR GROUP OF
     ''RUNS WILL BE PLOTTED WITH SUBROUTINE SCRIBE.
FOR EACH AH IN POSITION,FIND THE FIRST CASE
LET B1=TIME
FOR EACH AH IN POSITION IN REVERSE ORDER, FIND THE FIRST CASE
LET B2=TIME
PRINT 1 LINE WITH J,B2-B1,I2 AS FOLLOWS
          DURING RUN NO. ***, AH WAS IN PLAY FOR **.*** MINUTES,I2= *
CALL SCRIBE(AHX(*),AHY(*),ARTYX(*),ARTYY(*),X.MAX,Y.MAX,K,L,J,I1,PK.X(*),PK.Y(*)
,PKS(*),NO.RUNS,PE.R,PE.D,AIMX,AIMY,FLAG2)
ALWAYS
LET J=J+1
IF J LE NO.RUNS,SCHEDULE A SCENARIO NOW
LET I=0  LET K=0  LET L=0  LET I1=0  LET FLAG=0
LET FLAG1=0   LET FLAG2=0
FOR EACH AH IN POSITION,DO
REMOVE THE AH FROM POSITION
DESTROY THIS AH
LOOP
UNTIL N.EV.S(I.THREAT)=0,DO
LET THREAT=F.EV.S(I.THREAT)
CANCEL THREAT
DESTROY THREAT
LOOP
UNTIL N.EV.S(I.PREC.FIRE)=0,DO
```

```
LET PREC.FIRE=F.EV.S(I.PREC.FIRE)
CANCEL PREC.FIRE
DESTROY PREC.FIRE
LOOP
UNTIL N.EV.S(I.LOS)=0,DO
LET LOS=F.EV.S(I.LOS)
CANCEL LOS
DESTROY LOS
LOOP
RELEASE AHX,AHY,ARTYX,ARTYY,PK.X,PK.Y,PKS
RESERVE ARTYX(*),AND ARTYY(*) AS 999,AND PK.X(*),PK.Y(*),AND PKS(*) AS 999
SCHEDULE A THREAT IN UNIFORM.F(0.0,T1,5) MINUTES
IF OPTION EQ 1,
SCHEDULE AN LOS IN 1./6. MINUTES
ALWAYS
RETURN
ELSE
PRINT 1 LINE WITH STAT.1,STAT.2 AS FOLLOWS
          AVG P-K= *.*****   SD= *.*****
STOP
END
END OF RECORD CARD


USER'S DATA CARDS ENTERED HERE


6/7/8/9   END OF JOB CARD
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VITA

Emil H. Koenig, III was born in Houston, Texas on 7 February 1947. He graduated from high school in Houston, Texas in 1965 and attended Texas A&M University from which he graduated in May 1969 with a Bachelor of Science degree in Aerospace Engineering.

He entered commissioned service in the USAF through Officer Training School in 1969. After completing pilot training at Webb AFB, Texas, he operationally flew the F-106 at Dover AFB, Delaware; the F-4 at Udorn RTAFB, Thailand; and the O-2 at Bergstrom AFB, Texas. He entered the Air Force Institute of Technology in August 1977.

He is married to the former Sandra Gail Newman of Houston, Texas. They have two daughters, Cindy and Lisa.

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